THE SCIENTIFIC MONTHLY

MARCH, 1943

COLORATION OF ANIMALS AND THEIR ABILITY TO CHANGE THEIR TINTS

By Dr. G. H. PARKER

EMERITUS PROFESSOR OF ZOOLOGY, HARVARD UNIVERSITY

THE casual visitor to any of our larger zoological museums ordinarily carries away with him the impression that tropical animals, especially birds and butterflies, are possessed of what may be called a riot of color. The whole spectral range, blue, green, yellow, orange, and red, singly or more often in combination, is represented in these inhabitants of the tropics with such bewildering diversity and often in such brilliancy that their possessors may be said to be veritable living jewels. Our visitor, if he be at all observant, may also have noticed that the animals from the temperate regions are commonly of sober tints, for the most part dun-colored, and that those from the polar areas are in many instances white. Of what uses these various color schemes are to their possessors, how they may be subjected to control by the animals in which they occur, and by what steps they have arisen are questions that have long puzzled the naturalist and that remain today only very imperfectly answered.

Some of the most striking of these color conditions were known to the ancients. Aristotle described with remarkable accuracy the changing tints of devilfishes and of chameleons and further pointed out their probable significance in the economy of such animals. His descriptions of these phenomena are so true to nature that he must have observed them on the living creatures in their native haunts. But the intensive study of these matters is limited to the last hundred years or so during which an enormous accumulation of new observations has been made and much speculation on the subject has been provoked. This has led to a great diversity of opinion with the result that on many questions sides have been taken and heated debates have ensued. Only a few decades ago no less distinguished a person than a former president of the United States and an equally well-known American artist crossed swords on certain animal-coloration issues which brought particular aspects of the subject into momentary prominence. After the heat of the battle had subsided in this Roosevelt-Thayer conflict it was evident to an impartial critic that, as in most such cases, both sides were partly in the wrong and partly in the right. Although interested and distinguished scholars of this subject the world over have taken part in such contests, nowhere else than in these United States has the once head of a government entered the arena. Possibly this is a measure of what real democracy is and indicates a degree of liberty enjoyed not only by citizens of such governments but by their chiefs, though denied to those who rule even the closely related bodies as, for instance, constitutional monarchies. Here at least

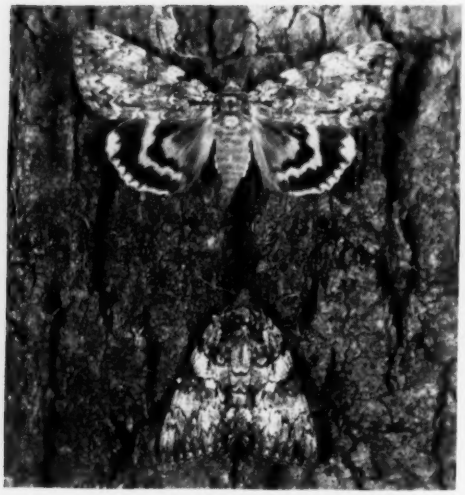


FIG. 1. UNDERWING MOTHS
PHOTOGRAPH OF MUSEUM SPECIMENS ON BARK: UPPER, WITH SPREAD WINGS; LOWER, WITH FOLDED WINGS.

the governmental heads, so far as I am aware, have never indulged in such activities, but have been so much engrossed with the doings of *Homo sapiens* that the color performance of their more lowly subjects have been allowed to pass unnoticed. But in whatever way the personnel of these discussions has been limited, the two extreme factions in such disputes, those who would belittle adaptive coloration or even deny its existence altogether and those who would see vital importance in every spot or mark on an animal's coat appear both to have missed the truth which seems very likely to lie in a middle ground of moderate interpretation maintained by the less excitable members of these forays.

When the substance of such discussions is impartially weighed there seems to be good reason for assuming that there really exist in nature many unquestionable instances in which coloration aids in concealment, in attracting attention, or in that type of imitation known as mimicry where one species of animal has stepped aside from its family form and coloration and has taken on the shape and markings of another species of quite different organization to the advantage of the imitator. It is also reasonably clear that many such well authenticated cases are extremely difficult to account for on the basis of the Lamarckian hypothesis of evolution, for in most instances among these animals the creature enters the world with its plan of coloration once and for all established and not subject to change by the later activities of the possessor, as muscles may be by use or disuse. This difficulty in explaining the evolution of most color patterns is not met with when Darwin's natural selection is invoked as the determining factor, for the animal with its given color coat is either a good fit or a poor one for its surroundings and hence is either more likely to survive, pair, and pass on its traits to its offspring or to die without leaving representatives. Hence the very presence of these types of coloration in nature is in itself a favorable omen for natural selection while it is on the whole a stumbling block to Lamarckism.

Animal Coloration in General

Before leaving these general aspects of animal coloration, however, it may be well to look for a moment at what have been regarded as good instances of the important types of this phenomenon. In a recent volume on this subject by the distinguished English zoologist, Hugh B. Cott, examples of animal coloration have been classed under three principal heads, concealing coloration, coloration for advertisement, and disguising coloration in which has been included those remarkable instances of specialization in form and tint known as mimicry.

Concealing coloration, to consider this class first, is well represented throughout the animal kingdom, but is especially often met with among insects. Although striking examples of this type of coloration are commonly assumed to be found only in distant and inaccessible parts of

the globe many of them occur near at hand, in fact at our very doorsteps. Of these the large noctuid moths of the genus Catocala are striking instances. The North American fauna is unusually rich in species of this genus known to every collector of our butterflies and moths. In some of these noctuids the spread of the wings may be three inches or more. In most species the fore or upper wings are dappled light and dark gray with some brown often interspersed and would be described on the whole as inconspicuously tinted (Fig. 1). The hind or under wings on the other hand have pronounced black marking on a mild background of red, pink, yellow, or white according to the species. In consequence of the striking coloration of their lower wings the members of this genus have been given the common name of underwing moths.

These moths can be found flying about in open woodlands even in the daytime and when on the wing are reasonably conspicuous. On settling down after flight they almost invariably come to rest on tree trunks and in so doing fold their colored underwings close to the body and cover themselves completely with the two approximated upper wings. The plan of coloration of the upper wings is so close to that of the trunks of the trees on which they rest that the closest scrutiny is often required to discover the moth as it clings to the bark (Fig. 1). In fact as this creature alights on a tree and covers itself with its upper wings it gives the impression of disappearing into the woody substance of its temporary resting place. Underwing moths when not in flight commonly rest on tree trunks in complete quiescence and are in consequence remarkably inconspicuous. It is well known to insect collectors that the darker species of Catocala frequent trees whose bark is dark such as oaks and the like and that the paler species are usually found on trees with paler bark like the beeches. Taking all in all it would be difficult to find a more perfect instance of concealing coloration than that shown by these moths, whose habits and color scheme aid so perfectly in their apparent obliteration.

A second example of concealing coloration is seen in the common crabspider, *Mitsumeria vatia*, of our countryside. This spider, the females of which may measure as much as half an inch in length (Fig. 2, A), is found very generally in the yellow flower clusters of the goldenrod. The tint of the spider agrees so exactly with that of the flowers that it is with the greatest difficulty that it can be seen nestled in among the yellow blooms. It is most easily discovered by shaking vigorously the flower clusters of the goldenrod over a shallow box whereupon the yellow crabspiders will be dislodged and easily caught. Under ordinary conditions these spiders rest hidden in the cluster of blooms (Fig. 2, B)

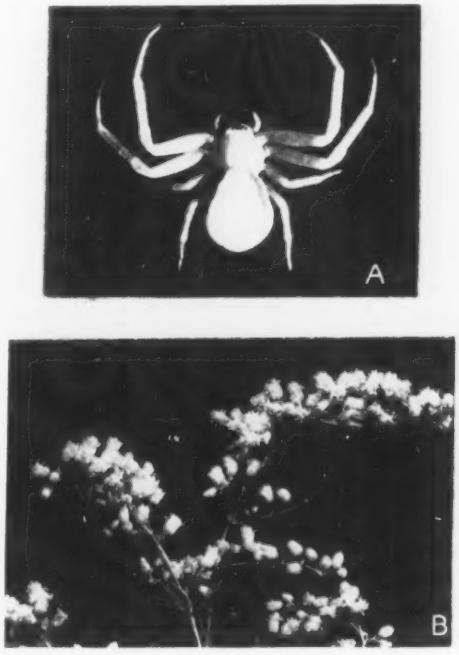


FIG. 2. CRABSPIDER

(A) FEMALE; (B) SPRAY OF GOLDENROD CARRYING TWO SPIDERS. ("THE SPIDER BOOK" BY J. H. COMSTOCK. 1912.)

where they remain unnoticed by the numerous insect visitants of the flower. The spider is thus enabled under favorable conditions to pounce unexpectedly upon its prey, seize the insect, and suck its juices. Though Mitsumena is not a large spider it is known to attack with success insects of the size of bumblebees. In this way the concealing coloration of the crabspider is an effective means in enabling this arachnid to obtain its supply of food. Mitsumena occurs not only on the yellow flower-clusters of the goldenrod, but also on the white masses of bloom of the wild carrot or Queen Anne's lace. When the crabspider is associated with the wild carrot it is white instead of being yellow in color. These color differences are said to be determined by the spider's environment.

The two examples of concealing coloration described in the preceding paragraphs, that of the underwing moth and of the crabspider, represent the two chief types of this kind of coloration. In the crabspider on the goldenrod the yellow color of the creature enables it to pounce successfully on its unsuspecting prey. This type of concealing coloration has therefore been called aggressive or offensive and is shared by not a few other animals. The mottled changeable color of the octopus or devilfish, as originally pointed out by Aristotle, enables this creature in its rocky habitat to creep up upon fishes unperceived and seize them as prey. The white coat of the polar bear in its background of snow aids this beast in its approach to and capture of its chief source of food, the seal, as this animal rests by its fishing hole in the ice. Many other instances of aggressive concealing coloration are known. These are, however, far outnumbered by the examples of the type of coloration for concealment represented by the underwing moth. In this instance the insect when at rest is overlooked by such foes as predatory birds and the like because of its resemblance to the bark of the tree on which it may have settled. Such a type of coloration has been called protective and in that sense is a defensive one. The group of insects abounds with innumerable examples of protective coloration, the green leaf-insects, the green and the brown walking-sticks, the multitude of green caterpillars with their rib-like stripes and hosts of other cases. Under this type falls the brown, mottled coloration of partridges and pheasants and the truly remarkable change of color in the pilage of the varying hare, dun-colored in summer and white in winter. Here also belongs the intense and varied coloration of tropical birds which though showy and brilliant beyond words in museum cases are lost to view in the tropical rain-forests where they flit about amid ever-changing intense shadows and sunlight and are indistinguishable from their surroundings in consequence of the welter of color change about them. Thus a host of instances of protective coloration with those of the aggressive type exemplify what has been designated as concealing coloration. These are Nature's efforts at camouflage so extensively practised now-a-days by man at war. We believe ourselves in this and other matters thoroughly up to date, but the palaeontologist can point to fossil walking-stick insects as far back in the history of the globe as the Jurassic Period, thus showing that these insects practised camouflage as long ago as 150 million years. Pride goeth before a fall.

The second general heading used by Cott in his discussion of animal chromatics is coloration for advertisement. A good example of this is the humblebee or bumblebee. Bumblebees are as much a part of the summer flower-garden as the flowers themselves. In their busy, ostentatious way these insects are the gossips of their native haunts and carry their stores of pollen from flower to flower, receiving a drop of nectar in return for what they bring. Though cumbersome, noisy, and fretfully active, they

are a part of their surroundings notwithstanding the conspicuousness of their color scheme. A garden without them would seem devoid of life, for they are fitted in size and color contrast with the world in which they live. Here they spend sunny days in full possession of what Nature gives them freely and man can not withhold. In general color they are dark, often really black and yet marked with conspicuous transverse bands or spots of yellow or even orange and red (Fig. 3). Kill me a red-hipped humblebee on the top of a thistle, says Shakespeare. Bumblebees are so common that we fail to note how conspicuous they are even amid the flood of colors of the summer garden. If the crabspider is tinted for concealment the bumblebee is colored for advertisement.

What the bumblebee advertises is its vicious sting. Sooner or later we learn to leave this insect to itself and more or less unconsciously set down its coloration as that of something to be avoided. The sting is an organ carried only by the queens and the workers, the two classes of females in the species. The males are without such organs yet notwithstanding this we avoid them as we do all other bumblebees without inquiring into their sex. Thus we court security even at the expense of knowledge.

The principle of advertising coloration illustrated by the bumblebee is believed to hold for the great majority of conspicuously colored animals. Creatures that in their natural haunts stand out as strikingly visible may well be suspected of harboring disagreeable and often dangerous traits. To this category belong the other stinging insects such as the common bees, and wasps and the brilliantly colored mutillas with their firy needles. Among the higher animals the skunk is believed to notify the inquisi-

American Museum of Natural History

FIG. 3. BUMBLEBEE AMONG APPLE BLOSSOMS

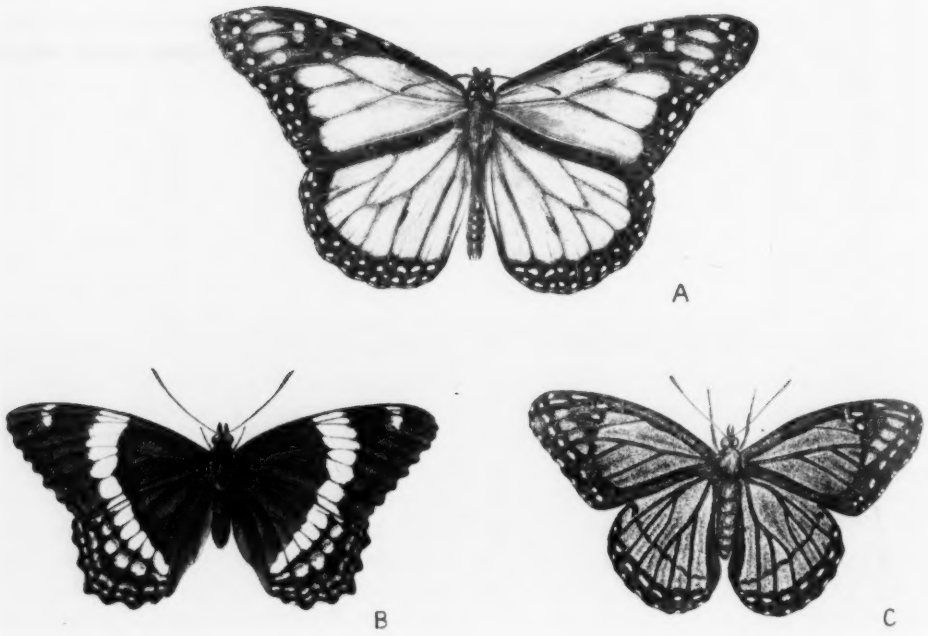


FIG. 4. MIMICRY OF THE MONARCH BUTTERFLY
(A) MONARCH; (B) BANDED PURPLE; (C) VICEROY.[1]

tive of its offensive traits by its highly contrasted coat. Such colorations are often described as warning.

The third and last general heading in animal coloration used by Cott is what he has designated disguising coloration and includes among other instances those of mimicry. This phenomenon is again best seen in the insects. In such instances a given species whose family coloration is of a definite type abandons this coloration and assumes that of another group of quite different organization. As already stated this change is believed to be to the advantage of the imitator. The animal imitated is commonly called the model and the imitator the mimic. An example of this kind is seen in two of our common butterflies, the monarch, *Danais plexippus*, and the viceroy, *Basilarchia archippus* (Fig. 4). The monarch (Fig. 4, A) is our largest butterfly and may in exceptional cases measure fully four inches across the wings. The body color of its wings is brown with dark veining and a fairly broad dark, almost black marginal band which is particularly wide at the outer angles of the forewings where there are numerous light spots. The monarch frequents open fields and is especially associated with milk-weed on which it lays its eggs. Hence it is often called the milk-weed butterfly. It is vigorous in flight and is noted for its extensive migrations. The viceroy butterfly (Fig. 4, C) is somewhat smaller than the monarch. Its wings spread at most three inches. The body color of the viceroy is brown, almost exactly that of the monarch. Its wings have a dark veining with marginal bands and pale spots in striking agreement with the corresponding parts in the larger insect. In fact

[1] (A) From "The Butterflies of the Eastern United States" by G. H. French. 1886; (B) From "Insects Injurious to Vegetation" by T. W. Harris. 1862; (C) From "A Manual of Zoology" by S. Tenney. 1872.

the two butterflies except for size are almost identical. The viceroy is also a butterfly of the open fields. Notwithstanding these numerous points of similarity the monarch belongs to a different subfamily, the Danainae, from the viceroy which is a member of the Nymphalinae. These two subfamilies differ structurally. Thus in the danaids the antennae are naked; in the nymphalids they carry scales.

When the other members of the two genera to which the monarch and the viceroy belong are compared a striking contrast is to be observed. The coloration of other danaids is brown and in very close agreement with that of the monarch. The near relatives of the viceroy on the other hand are dark in color and often of a purplish tone. Thus in the nymphalid known as the banded purple, *Basilarchia arthemis* (Fig. 4, B), the wings have a very dark ground tint with a concentric system of broad white bands and with rows of marginal dots and lunules some reddish and other blue thus giving it a purplish tone. Other members of the genus Basilarchia are in color much like the banded purple. None of them resemble the viceroy.

From these facts it is to be assumed that the monarch has remained true to its family coloration, but that the viceroy has departed from its traditional color scheme. In the combination of the monarch and the viceroy then the former must be the model and the latter the mimic.

In what respect does the viceroy profit by its change of coloration? The group of butterflies to which the monarch belongs is noted for their rank and disagreeable odor. Collectors of insects are familiar with this trait in all danaids. This feature may well be repellent to birds and other predacious animals. No such odor is associated with the viceroy which may, however, profit by its color resemblance to the monarch and be left untouched by the common foes of butterflies. Thus the viceroy is believed often to escape destruction which it might well otherwise meet. If monarch and viceroy are related as here outlined the geographical distribution of the two species ought to be such that the area occupied by the mimicing viceroy should be within that of the model monarch. If this were not so the mimic would be unprotected in its extraterritorial area. As a matter of fact in these two butterflies this condition is fully met. The monarch is found over the whole of temperate North America from the Atlantic seaboard to the Pacific coast and southward to the Gulf of Mexico. The viceroy on the other hand is limited to the eastern portion of this range and nowhere extends beyond it. Thus these two butterflies afford a good example of mimicry in their coloration and show in their areas of distribution a conformity to the theoretic requirements.

The three main classes of animal coloration as outlined by Cott have now been illustrated by one or two examples each and have received what may be described as a sympathetic presentation. What can be said by way of criticism of this whole treatment of animal coloration? The chief weakness of this view, inviting as it is in some respects, lies in the fact that it is almost purely hypothetic and lacks that kind of evidence which is ordinarily looked upon as conclusive. Such evidence must come from experimental tests. Are underwing moths really protected by resembling the bark of the trees on which they alight? Could not the crabspider if of another color than that of the flower head in which it lurks catch its prey with equal success? Such questions as these must be answered first before an unqualified assent can be given to the adaptive interpretation of animal coloration. Some experimental evidence on this general problem has as a matter of fact already been acquired, but it is scarcely more than a beginning. Sumner subjected

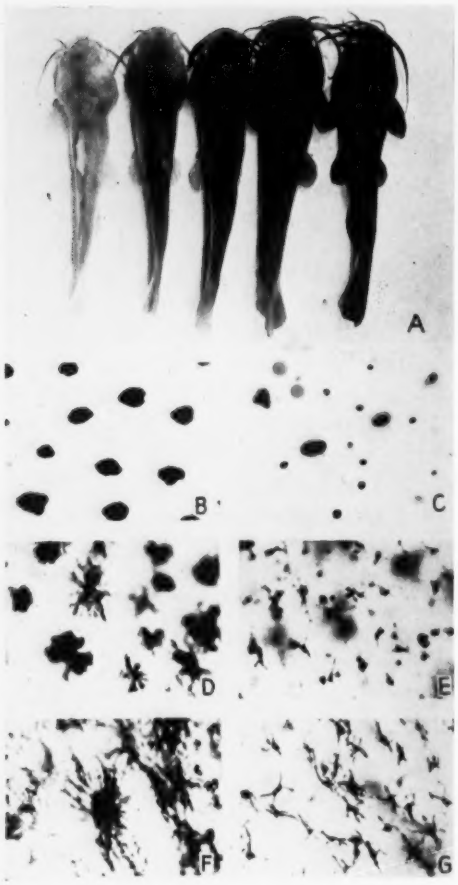


FIG. 5. CATFISH MELANOPHORES
SHOWING COLOR RANGE: (A) FROM PALE TO COAL-BLACK; (B), (D), (F) LARGE MELANOPHORES WITH CONCENTRATED, INTERMEDIATE AND DISPERSED PIGMENT; (C), (E), (G) SMALL MELANOPHORES WITH CONCENTRATED, INTERMEDIATE AND DISPERSED PIGMENT.

numbers of pale and of dark mosquito fishes, Gambusia, to attacks from several predators, the Galapagos penguin, the night heron, and the blue-green sunfish. In each trial equal numbers of dark and of pale mosquito fishes were liberated in one test over a black background and in another over a pale gray one. A predatory bird or fish was then allowed to feed upon them. As a result of these tests it was found that the mosquito fishes which fitted the backgrounds were less numerously seized and eaten than those that were of contrasted tint. In a general summary of the whole set of experiments made by Cott it was shown that of 2,672 fishes offered as prey 1,150 were reckoned as casualties of which 395 (34 per cent) were of the less conspicuous individuals and 755 (66 per cent) of the more conspicuous ones. Plainly there was shown in these tests a real advantage to the possessor of the so-called protective coloration. It is experimental evidence of this kind obtained either from the laboratory or from the field that will settle many current problems of animal coloration and such settlement will be more conclusive than that based on wordy discussion.

Animals with Rapid Color Changes

Animals with the remarkable capacity of rapid color change have long been known and their significance for the general theory of adaptive coloration has been fully recognized. Beside a few sporadic instances of this kind of change among such creatures as the sea-urchins, the leeches, and the insects, the animals that show this remarkable capacity are found in three independent groups, the cephalopods such as the devilfishes and squids, the crustaceans including the shrimps, prawns, crabs and the like, and the cold-blooded vertebrates, the fishes, frogs, salamanders, and many of the reptiles especially the lizards. Among the vertebrates the fishes have received perhaps the most attention and these animals will serve as a basis for the following account.

The majority of fishes can be shown to exhibit more or less change of color. In tests of this kind some fishes like the squirrel fish of Bermuda will change from pale to dark or the reverse in a few seconds while others, such as the common New England catfish, will require from one to several days to make these altera-

tions (Fig. 5). Color changes are brought about by readjustments in the pigment content of the color-cells, or chromatophores, in the skins of these animals. The most usual kind of vertebrate chromatophore contains granules of black pigment and is known in consequence as a melanophore. In the pale condition of such a fish as the catfish the pigment is collected about the centers of the color-cells (Fig. 5, B); in the dark condition it is scattered throughout the bodies of the cells and their processes (Fig. 5, F). The shifting of the pigment back and forth within the color-cell is what changes the tint of the fish.

In addition to the melanophores many fishes possess true color-cells with characteristic pigments: xanthophores with yellow, erythrophores with red, and leucophores with white. In many fishes there are groups of crystalline plates which vary greatly in color and which are covered or exposed by the migration of the pigment in the surrounding melanophores. Such combined structures are called chromatosomes.

Depending upon their chromatophores different fishes exhibit different degrees of color activity. The common catfish possessing only melanophores has a limited color range from a pale greenish yellow to a coal-black (Fig. 5). In the killifish in addition to melanophores there are xanthophores, leucophores and green-blue chromatosomes. These fishes change not only from dark to pale (Fig. 6) but they may assume yellow, green, blue or even red tints. The red coloration is due to an enlargement of the integumentary blood vessels, a true blush. The color changes in tropical fishes are like those in the killifish except that they are much more exaggerated. In some of these fishes even the general pattern seems open to change, almost to obliteration, as in the Nassau grouper (Fig. 7). The southern flatfish, Paralichthys, will respond roughly to different checkerboard patterns by becoming more finely or coarsely spotted (Fig. 8) in accordance with its background. Such pattern changes, mostly due to melanophores, when coupled with true color changes give tropical fishes an almost limitless range of tints.

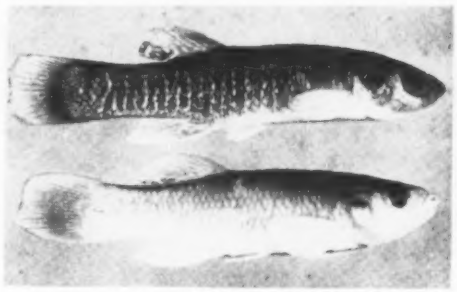


FIG. 6. KILLIFISH
UPPER, DARK PHASE; LOWER, PALE PHASE.

How these color changes in fishes are controlled has been a problem for a century past. In 1852 Brücke pointed out that when cutaneous nerves in the chameleon were cut, the areas of skin thus

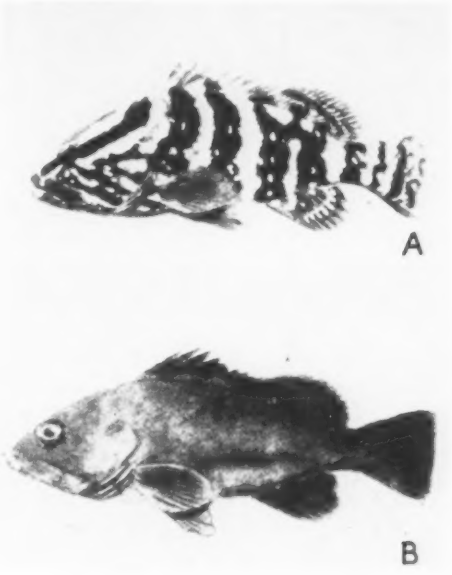


FIG. 7. NASSAU GROUPER
(A) PALE PHASE; (B) DARK PHASE. ("CAMOUFLAGE IN NATURE" BY W. P. PYCRAFT. 1925.)

denervated darkened by the dispersion of their melanophore pigment. In 1858 Lister, then a young student of medicine, discovered that in the common frog the eyes were essential to color changes and declared in favor of a nervous interpretation of vertebrate chromatism. Pouchet, whose work on fishes (Fig. 9) confirmed that of Brücke on the chameleon and of Lister on the frog, showed that the part of the nervous organization concerned with color changes was the sympathetic or autonomic system, a view subsequently supported by von Frisch and many other workers. Thus the nervous interpretation of the phenomena of color change in vertebrates became paramount.

Meanwhile Hogben and Winton, who had been actively engaged in the study of the chromatism of the frog, were led to conclude from their experimental tests that in this animal nerves played a wholly insignificant part in color change if in fact they played any part at all. Evidence obtained from experiments on the frog's pituitary gland which is situated in the base of its brain led these investigators to declare that the dark color of this amphibian was due to a substance, a hormone, produced in the pituitary gland whence it was carried by the blood to the melanophores throughout the body. The pale color of this animal they believed to be due to the absence of this substance. Thus the occasion of the color changes in this amphibian was shifted from nerves to a blood-borne hormone. This substance, later called intermedine, thus became the all-important factor in the chromatism of the frog. From this and other work it was concluded that though the color changes in fishes and reptiles were dominated by nerves those in amphibians were essentially hormonal.

This novel and somewhat anomalous situation stimulated further work on the color changes in the lower vertebrates

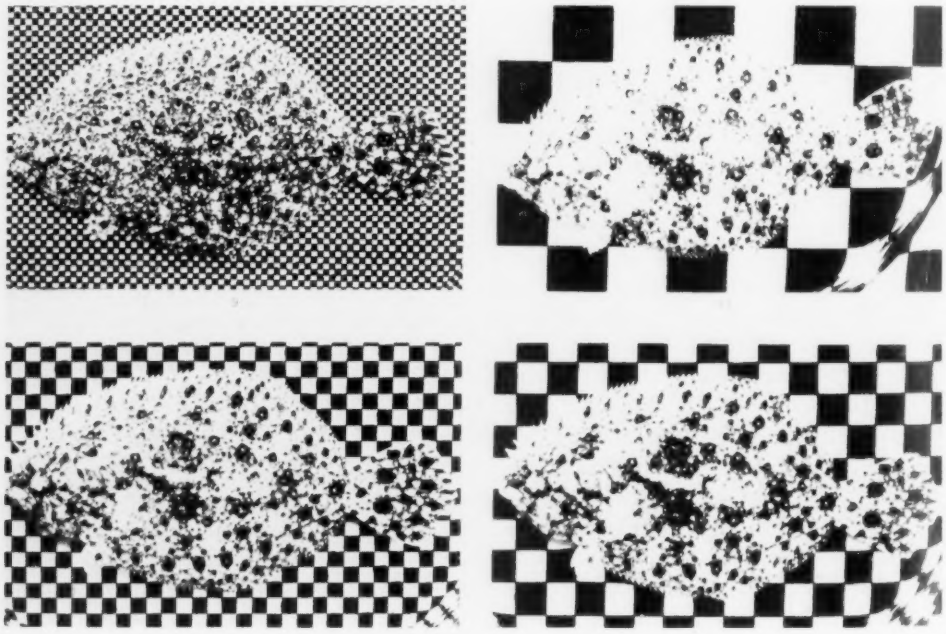


FIG. 8. THE SAME INDIVIDUAL FLATFISH ON FOUR DIFFERENT CHECKERBOARD PATTERS. (S. O. MAST, BULL. U. S. BUR. FISH. 1916.)

particularly in the fishes. Much of what is new in this field can be illustrated by the color responses of the common New England catfish Ameiurus. As already stated this fish ranges in tint from a pale greenish yellow to a coal-black (Fig. 5, A). It possesses only melanophores. These are of two kinds large in the derma and small in the epidermis. In the pale phase the pigment in each color-cell is reduced to a dot large or small (Fig. 5, B and C); in the dark phase it is spread throughout the color-cells and their branches (Fig. 5, F and G).

To what extent are the color-changes in fishes like the catfish under the control of nerves and is there any evidence of hormone action in such creatures? In the catfish as in many other common fishes there is good evidence that the color changes are at least partly under nervous control. If, following the procedure originated by von Frisch, a particular spot in the medulla oblongata of the catfish is stimulated electrically, the whole fish will quickly blanch (Abramowitz, 1936). This response, however, does not include denervated areas. Hence it must be nerve activity that induces it, for where nerves are absent it fails to appear. Thus the concentration of melanophore pigment in the catfish must be occasioned by nerves. Responses of this kind have been observed many times in numerous fishes and have long been accepted as conclusive evidence for the presence of concentrating nerve-fibers in these animals. The opinion that this type of nerve-fiber is present in fishes and as a matter of fact also in certain lizards seems established beyond all doubt.

Whether there is an opposing type of nerve control for melanophores is not so easily demonstrated. From the time of Brücke it has been believed that the dark areas of skin due to the cutting of cutaneous nerves is the result of the paralysis of the concentrating fibers and their

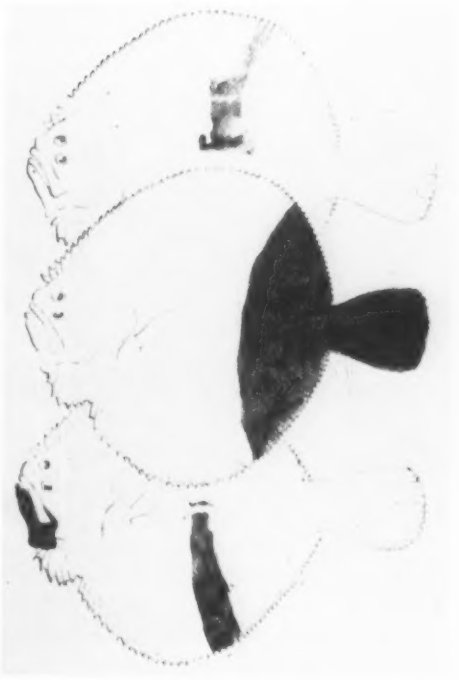


FIG. 9. TURBOTS
WITH DARKENED AREAS DUE TO DENERVATION.
(POUCHET, JOUR. ANAT. PHYSIOL. 1876.)

color mechanism. It is possible, however, to show the incorrectness of this view even on the catfish. If a bundle of nerves in the tail of a pale catfish is cut, a dark denervated caudal band will quickly appear. This band represents what the older workers regarded as the paralyzed region of the color system. After a day or two, however, such a band will blanch considerably and if now it is recut in a region slightly distal to the initiating cut, the band will again darken (Fig. 10). Such a redarkening could not occur if the band was actually paralyzed, for the band should then be inactive. This second darkening makes it clear that the color mechanism of the band is still functional and far from paralyzed. Hence the view that the caudal and other like bands are palayzed must be incorrect. The most probable explanation of this phenomenon is that the cut chro-

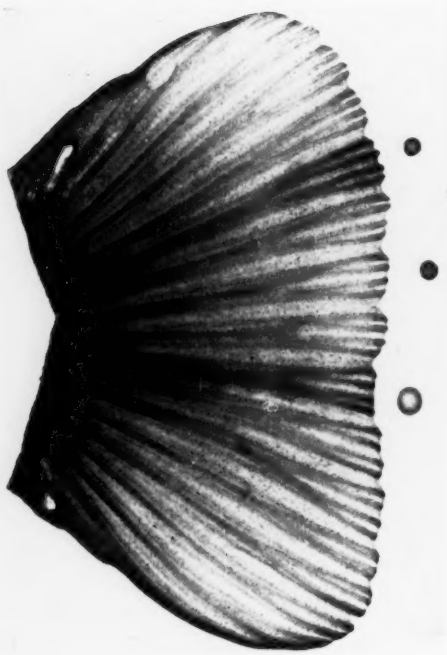


FIG. 10. TAIL-FIN OF CATFISH WITH CAUDAL BANDS. UPPER BAND PARTLY BLANCHED (COMPARE WITH OTHER PARTS OF TAIL, FULLY BLANCHED); LOWER BAND PARTLY BLANCHED AS UPPER BAND WAS AND THEN RECUT, IN CONSEQUENCE OF WHICH IT HAS DARKENED (COMPARE LOWER BAND WITH UPPER BAND).

matic nerve contains at least two sets of fibers one of which, the concentrating set, is open most easily to electric stimulation and the others, the dispersing set, is stimulated most easily by cutting. Such a view implies double innervation for catfish melanophores and puts them in the same category as the heart-muscle of the higher vertebrates where one set of nerve-fibers accelerates and the other retards this organ. It is interesting to observe in this connection that in the innervation of the melanophores of the perch and other fishes as worked out histologically by Ballowitz in 1893 not one but several nerve-fibers as a rule are distributed by numerous terminals to each color cell (Fig. 11). Of course one fiber might well be a concentrating element and another a dispersing one. Thus even the histological findings in this field are favorable to the idea of a double innervation. As a matter of fact double innervation of chromatophores was long ago suggested by Bert (1875) for these cells in the chameleon, but without supporting experimental evidence. This view of chromatophoral innervation at least in the common fishes seems now to be gaining more general credence (Waring, 1942) than when it was reaffirmed a decade or so ago (Parker, 1932).

From the evidence thus far presented it is clear that the catfish like other members of its group has a very complete nervous mechanism for the control of its melanophores. Nor is there any reason to believe that it needs more. It is, however, not without importance to raise the question whether this fish may not possess other means of controlling its melanophores than the two sets of nerve-fibers already described. If such another activator were present it might well be the secretion from the pituitary gland, intermedine. After the removal of this gland from a catfish the creature presents a remarkable limitation in its capacity for color change (Abramowitz, 1936). Although such a fish can become fully pale, it is unable to darken in normal dark surroundings to more than what would be called an intermediate stage (Fig. 5, A, D and E). Apparently this is the limit of efficiency for the dispersing nerve fibers, the one obvious darkening agent left. If into such a partly dark fish a quantity of intermedine is injected, the fish will darken fully. This test indicates that the complete darkening of a catfish is dependent upon intermedine which can also be shown to be capable in itself of carrying catfish from a completely pale to a completely dark state. Hence catfishes appear to have another darkening agent in addition to the dispersing nerve-fibers, namely the pituitary hormone, intermedine. They thus may be said to

possess in all three well established melanophore activators: for darkening, pituitary intermedine and dispersing nerve-fibers; and for blanching, concentrating nerve-fibers.

The catfish, from the standpoint of its kinds of melanophore control, presents an extremely interesting condition, for it possesses not only a nervous mechanism in its color system but also a hormonal one. This combination, which is found in a number of other common fishes, indicates a much closer relation between these two means of color control than that implied in the general statement that fishes and reptiles activate their color-cells by nerves and amphibians by hormones. How in fact are these two systems related?

The hormone intermedine is produced in the pituitary gland of the brain whence it is carried in the blood and lymph of the fish to the melanophores in the skin and pigment of which is thus stimulated to disperse. This is a very simple and direct way of applying an activating agent to its responding part. How do the two sets of chromatic nerve-fibers stimulate color-cells? These two sets of fibers belong to the autonomic nervous system and might well be supposed to act on the color-cells through the two activators so common in this system adrenaline and acetylcholine. Is there any evidence that these substances are associated with the catfish color system?

Appropriately made extracts of catfish skin can be examined for adrenaline by a biochemical test as shown in the responses of a Straub frog-heart preparation. Adrenaline is destroyed by heat. When unboiled and boiled extracts of catfish skin are applied separately to Straub frog-heart preparations, a vigorous response is elicited by the unboiled extract and a very faint reaction by the boiled one. As these tests are specific for adrenaline the excess of response to the unboiled over the boiled extract must be due to this agent. It is therefore clear that the unboiled skin extract must contain some adrenaline. Bray showed as early as 1918 that 0.2 cc. of adrenaline one part in a million of Ringer's solution would on injection blanch a whole catfish, an observation substantiated by many subsequent workers. Taking these several observations together it is beyond doubt that adrenaline is a constituent of the catfish skin and it is very probable that it is the agent which in conjunction with the concentration fibers induces the melanophores of this fish to concentrate their pigment.

In a similar way a biological test for

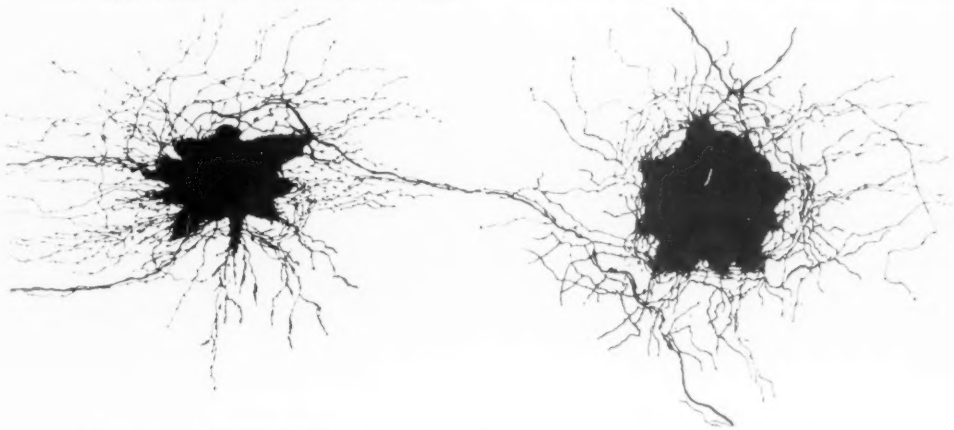


FIG. 11. INNERVATION OF TWO MELANOPHORES IN THE PERCH
(FROM BALLOWITZ, ZEIT. WISS. ZOOL. 1893.)

acetylcholine can be made use of in the responses of strips of leech-muscles to appropriate fish-skin extracts. This method moreover allows of quantitative results. By its use the amount of acetylcholine per gram of wet fish skin has been found to be 0.078 gamma or about one part of acetetylcholine to 13 million parts of skin. It is not easy to appreciate the smallness of this quantity of acetylcholine. If we assume the distance from Boston to New York, some 230 miles, to represent a gram of skin, the weight of acetylcholine, 0.078 gamma, would be equal in such a distance to about an inch. This comparison may give us some conception of how small the effective amount of this agent is in a catfish's dark skin. While this determination was being worked out in the Harvard Laboratories another made by the same method was published by Chang, Hsieh, and Lu of the Pekin Union Medical College on the skin of the Chinese snakefish. The determination by these investigators was 0.077 gamma of acetylcholine per gram of skin. The closeness of these two determinations must be regarded as in a measure accidental, for it is unlikely that such uniformity exists. The two numbers, however, show in their approximation the order of magnitude of the amounts of acetylcholine involved and make it fairly certain that these amounts are prodigiously small. Acetylcholine when injected into catfishes with proper precautions will darken them. Hence this substance may well be the agent associated with the dispersing nerve-fibers in their darkening effect on the catfish skin.

If, as is suggested by the preceding consideration, concentrating nerve-fibers act on melanophores through adrenaline, and dispersing fibers through acetylcholine, the melanophores must be subject to much the same type of stimulation by nerve-fibers as by intermedine in that in both instances there is a direct application of a dissolved activator to the outer surface of the color-cell. This tentative view leads to two important conclusions. The first is that the frequently made distinction between stimulation of color-cells by hormones and by nerves is of very little significance, for both methods are in reality the same and depend upon dissolved materials applied to the color-cells. And the second conclusion is that the type of stimulation in the chromatic system falls exactly in line with what is being developed at present for the nervous system in general, namely, that one nervous unit, be it sense cell, nerve cell, or appended cell, is stimulated by another not through purely electric disturbances that pass from one unit to the next, but by substances such as the three herein named. These substances are generated by the discharging unit and activate the receiving one. According to this view such substances are the universal means of passing impulses from one element in the nervous system to the next and are thus of first importance in the physiological integration of nervous activity. They have been variously called chemical activators, neurohormones, transmitters, neurohumors, and the like, but the substances thus designated all act to the same end, the transmission of nerve impulses from one nervous unit to its neighbor. It is gratifying to observe that the study of the color changes of animals supports this general conception of nerve activity, perhaps one of the most important steps in the modern study of the nervous system, that system of organs which has more to do with making us what we really are than any other system in our whole physical organization.

PERENNIAL SNOW AND GLACIERS[1]

By Professor J. E. CHURCH

METEOROLOGIST, AGRICULTURAL EXPERIMENT STATION, UNIVERSITY OF NEVADA; PRESIDENT, INTERNATIONAL COMMISSION OF SNOW AND GLACIERS

Perennial snow differs from seasonal snow chiefly in its survival, and the difference in age between new and old snow may be a matter of days or even hours. Their physical difference, however, may be extreme.

Snow Density

New snow lacks initial coherence though its density may vary from the fluffiest snowflakes to the wettest slush. The lightest density recorded on the ground at the time of fall is 0.4 per cent (0.004) water equivalent in Sodankylä, Finland, during the winter of 1917–18, and a snowfall of 0.5 per cent water equivalent was recorded at Charles City, Iowa, during the winter of 1904–05. However, it is difficult to determine with precision the density of either fluffy snow or feathery rime because of the irregularity of the surface.

Snow density varies primarily with temperature, humidity and wind. The simpler crystals, whether columns or plates, are formed where the air is cold and therefore at high altitudes, whereas the complex star-shaped crystals are formed in relative warmth, and by the interlocking and refreezing of their fern-like points may form combined snowflakes of two to three and probably four inches in diameter.[2]

Furthermore, because of difference in absolute humidity the columns and plates are sparse and the stars dense. On the other hand, because of simplicity of form the columns and plates will pack together under movement more readily than the stars, thus simulating water-laid sand.

Paradoxically, the cold-born snow, though initially lighter, soon becomes denser than the warm-born snow and quickly approaches maximum density. The transition was noticed during winter observations on the inland ice of Greenland. The measurements were made by Helge Bangsted (unpublished report). In no case did the depth of "new-born" snow exceed 1.4 inches, so small was the quantity. Therefore gravity had little or no part in the increase in density. The temperature ranged from −17.2° to −15.0° C. (+0.4° to +5.0° F.). The air was still. The snow density at the two temperature extremes was 3.6 per cent, or about one-third of the formular density of 10 per cent. During the night at a temperature of −18.1° C. (−1.0° F.), but during wind the density increased to 11.5 per cent (average of four measurements); where the snow was less exposed to the wind the density increased to only 5.6 per cent.

New snow after apparently only a day or a night of drifting attained an average density of 17.6 per cent. Later in the same period snow only 2.9 inches in average depth attained a density of 24.3 per cent. The density of old snow (depth 5.8 inches) was found to be as high as 28.0 per cent. Drift snow (depth 7.2 inches) after sufficient movement to cover the sled had a density of 35.4 per cent.

[1] This is the third in a series of articles by Dr. Church on "The Human Side of Snow." The first appeared in February, 1937, and the second in March, 1942.

[2] "Heavy precipitation (intense rate) favors large flakes, also rather quiet air. The fluffiest snows come in weather too cold for flakes to form except by the enmeshing of the points of complex crystals."—Dr. Charles F. Brooks in Report of Research Committee on the Hydrology of Snow, *Trans. Amer. Geophys. Union*, p. 442, 1942.

Ernie Mack

WINTER SNOW IN ITS EARLY STAGE, SIERRA NEVADA MOUNTAINS

But high-mountaineers are not always fortunate in finding wind-packed snow along their route. Soft snow was found by Whymper at 20,000 feet in the Andes. He wrote, "Louis Carrel could not touch bottom with a twelve-foot pole that he was carrying. It would have continued to descend by its own weight if he had left hold of it . . . as the slope steepened the snow became firmer again."[3] FitzGerald encountered at 18,700 feet on Aconcagua, Chile, in the Andes, "high clouds of driven snow, fine as sand, which nearly suffocated them," and "fell into a huge drift of soft snow."[4] The minimum temperature was −28° C. (−18.4° F.). Of the Himalayas, Odell writes, "Our soft snow on Nanda Devi up to 25,000 feet was in a more or less sheltered reentrant of the mountain, while the exposed summit calotte (25,645 feet) had on the whole a harder compacted surface, although not uniformly so. The more sheltered parts of the flanks of Everest's north face are of soft floury snow, and there is on the whole only restricted windslab on the more salient portions."[5]

However, wind-blown snow quickly acquires a high density which is only slightly increased during the season. The firmness of this snow under foot usually makes mountain ascents easier in winter than in summer.

Capillarity

Snow density is not necessarily synonymous with grain size nor with loss of capillarity known as ripeness.

As snow ages, the more delicate points and angles of the crystals melt or sublimate to rejoin the residual nuclei and increase their size, but at the expenditure of the tiny capillary canals and the larger superficial area of the original grains.

Density expresses water equivalent and crystals of large size and large voids may not possess the capillarity of the smaller crystals unless the voids have become filled by congealing melt water. This lack of capillarity in coarse grains is due to the tendency of melt water to follow the contour of a crystal and form a film about it by surface tension instead of filling the voids. However, if the mass is supersaturated and adhesion is no longer possible, the water flows by voids or conduits, called gravity flow.

New snow exceeds old snow in capillarity but windblown snow because of the smallness of its voids loses little of its early capillarity with age.

On the basis of density, snow may become ripe or unable to sustain its water load at 30 per cent density. The average of many measurements indicates limits of 30.1–36.2 per cent where the crystals are somewhat protected from breakdown by wind action, and 38.2–48.4 per cent where the snow is windblown. After weathering begins, the grain size does not greatly change unless exaggerated by repeated thawing and freezing or by pressure, and the density of the various strata including crusts tends toward uniformity.

Solid ice naturally has no capillarity beyond the surface tension of its exterior and therefore responds immediately to melting.

Insolation

Although warm turbulent atmosphere establishes direct thermal contact with the snow and may produce floods, insolation or exposure to the direct rays of the sun is seasonally more effective because of its longer application. The surface of the snow near midday in sunlight may melt although the air temperature in the shade is −10° C. (18° F. below freezing).

[3] "Travels Amongst the Great Andes of the Equator," by Edward Whymper, pp. 68, 71 (Ascent of Mount Chimborazo, Ecuador).

[4] "The Highest Andes," by E. A. FitzGerald, pp. 89, 92, 114.

[5] Unpublished correspondence, International Commission of Snow, Washington Meeting, 1939.

Ernie Mack

EARLY WINTER SNOW IN THE SIERRA NEVADA

C. H. Diebold, of the U. S. Forest Service, reports that melt rates in the open have been found to be from 1.5 to 2.0 times that in the forest,[6] where shading is relatively complete. Visual evidence of this protection is abundant in the lee of forest screens where the snow line is identical with the line of shade. Likewise in the open, the insolated and shaded sides of snow even of small size melt at unequal rates.

An impressive example to travelers by bus over the Sierra Nevada was the disparity in the melting rate of the opposite snow walls cut by snowplow on the Donner Pass highway in February, 1942. The wall exposed to the sun had retracted from 6 to 12 inches behind the markers set to indicate the edge of the pavement while the shaded wall was still in its original location or at least was flush with the markers. From bottom to top of the pass the height of the walls varied from approximately 4 to 10 feet but the retraction showed practically no variation with increase in altitude (6,000–7,000 ft.) but rather with the angle of incidence of the sun. During this period at Soda Springs near the summit of the pass the extreme maximum temperature was 46° F. and the minimum −16° F. The mean air temperature above 32° F. (or freezing) was only 2.6° F.

A recent but unusual example of this disparity between sun and air temperature was the formation of snow reliefs in shadows of slender survey-markers set up in the snow. These reliefs, which were plainly visible, had identical orientation, pointing from the sun at the time of its greatest heat efficiency near mid-afternoon.

Dr. Robert E. Horton suggests that, if possible, comparative laboratory or controlled tests be made of melting rates of snow in the same ambient atmosphere with one sample exposed to the sun but the other in the shade. Ideal conditions,

[6] Min. Eastern Snow Conference, Sept. 8, 1941, p. 9 (Mimeo.).

DRIFT SNOW

IN THE LEE OF AN ICE HUMMOCK ON THE GREENLAND INLAND ICE. THE RELATIVE DEPTH OF THE SNOW IS SHOWN BY THE HOLE IN FOREGROUND.

Ernie Mack

EARLY STAGES OF INSOLATION

AND FORMATION OF SUN CUPS NEAR SODA SPRINGS, SIERRA NEVADA, AT AN ELEVATION OF 6,767 FEET.

Ernie Mack

UNEVEN MELTING IN SUNSHINE

CAUSED BY SELF-SHADING. ORIGINALLY THE ROOF WAS EVENLY COVERED WITH SNOW, EXCEPT FOR A SNOW CORNICE ON THE RIGHT. SOON AFTER THE PICTURE WAS TAKEN THE SNOW REMNANT OVERBALANCED AND FELL FROM THE ROOF. APPARENTLY THE INSOLATED FACE OF THE SNOW COVER ON THE LEFT MELTED FOUR TIMES FASTER THAN THE SHADED PART ON THE RIGHT. THE OPAQUE ROOF ACCELERATED MELTING FROM THE SIDES AND BENEATH.

however, would require dazzling, fresh, soft snow, possessing a possible maximum albedo or reflectivity of 87 per cent, in order to exclude the radiation of heat that occurs from opaque objects in the snow. Care must also be taken through air-conditioning to prevent "greenhouse" influence on the insolated sample of snow.

Dr. Brooks suggests "the need for the application of observed insolation to different slopes. The network of U. S. Weather Bureau solar stations in the United States now is almost sufficient for fairly close estimates of the insolation impinging on any slopes. More stations would be desirable."

The depth of penetration of the sun's rays into snow has been found by Kalitin[7] to be 15 centimeters (5.9 inches) for wet snow and 60 centimeters (23.6 inches) for dry. On the Greeland inland ice, 1926–1928, the author found that opaque bodies sank only pencil deep (6–7 inches) into the ice where they re-

[7] N. N. Kalitin, Measurements of the Albedo of a Snow Cover, *Mo. Weath. Rev.*, Feb., 1930.

WIND BLOWN SNOW, CREST OF MT. ROSE, SIERRA NEVADA MOUNTAINS

mained inert. The diameter of the holes was proportional to the area of the opaque material, tiny objects producing a hole the diameter of a lead pencil. Most holes were crescent-shaped and tilted toward the sun as in the case of the pinnacles of the *nieve penitente*. The shallowness of the holes was probably due to the presence of melt water that could not escape.

At 6,000 feet in the vicinity of Soda Springs at the end of March, 1942, suncups in the snow cover had attained a depth of five and one half inches irrespective of the diameter of the opaque material causing them, tiny pipe-stem holes being as deep as the others. Since the water drains off freely, there may be an opportunity here to study the proportional growth of cups of varying areas unaffected by water blanket.

Here within the sweep of the rotary snow plow, ejecta of soil and gravel on the snow surface provided a complete exhibit of radiation effects from the inverted cone containing a single pebble, through the broad cup produced by several separate pebbles acting in unison, to the mound protected from the sun by thick material as completely as the ice beneath the Arctic tundra.

Likewise the pavement after a storm carries the story of radiation in the ice film still clinging to the white concrete and the dry surface of the black asphaltum. Similarly the trees hold their white loads of snow so long as the sun is hidden by clouds but when the sun's rays touch the bark or needles radiation from them disengages the clasp of the snow, which soon slips and falls from its precarious perch.

On the open snow incipient pinnacles, suggesting miniature snow spray, mark the break down of the snow surface. Occasionally an ice window-pane over a depression provides green-house warmth to accelerate melting.

Rates of Melting

The rate of melting depends fundamentally upon the sun's warmth and the length of its application. A daily rate is unsatisfactory, for the length of the melting day varies with altitude and cloudiness. For example, at Soda Springs (6,767 feet elevation) the daily period December–April does not normally exceed 6 hours and the snow surface begins to congeal while the air temperature in the shade above it may still be 35° F. or even higher.

EFFECT OF A TIMBER SCREEN
IN RETARDING THE MELTING OF SNOW IN ITS LEE, NEAR LAKE TAHOE, SIERRA NEVADA MOUNTAINS. THE SNOW AND SHADE LINE ARE IDENTICAL.

During the month of April, the average daily melting per degree F. above freezing for the years 1936–1941 was 0.051 inch of water and the maximum divergence for these years was only 0.015 inch, despite variation in depth and density. The temperature above freezing is plainly the controlling factor.

Flood intensity in snowfields depends upon rate of melting but flood magnitude upon its continuance without interruption. An extremely high natural rate

of melting has been reported by David W. Hullinghorst, U. S. Engineer Office,[8] for the Canacadea Creek Basin, New York, April, 1940, when 1.25 inches of runoff were generated in approximately four hours on the 60-square mile area, or 0.313[9] inches hourly for the period. He suggests that when the snow reaches a critical state, it becomes slush and moves when the crystalline network breaks down. He continues, "The thermal quality appears to be an index of the critical condition but at least one other index, probably density, is required to fully define the critical condition."

[8] Minutes Eastern Snow Conference, Sept. 8, 1941 (Mimeo.).

[9] On the basis of a 6-hour melting day at Soda Springs or .076 in. hourly, the flood melting at Canacadea Creek Basin was four times the long time average at Soda Springs. The temperature is not available.

The estimate by Hullinghorst represents the average melting for an entire basin rather than the maximum rate at any point.

Beneath the snow cover is an individual world inviting the searcher's acquaintance: the formation of crusts and their growth from daily thawing and freezing, the effect of latent heat in accelerating melting and of porosity in hastening freezing, the diurnal freezing and thawing within the snow-cover despite the accepted non-conductivity of snow, the perched strata of rain water imprisoned in the snow isolated from the dry granular snow below and its early release with rising temperature, the crystal change until at last the snow is gone. All these and more are themes in the project of snow studies now organized at Soda Springs by the Nevada Agricul-

Ernie Mack

EFFECT OF OPAQUE MATERIAL IN PITTING THE SNOW
IN THE SOUTH YUBA BASIN OF THE SIERRA NEVADA MOUNTAINS.

tural Experiment Station and the United States Weather Bureau with the informal but sympathetic cooperation of many organizations grown interested in snow through the years.

Glaciers

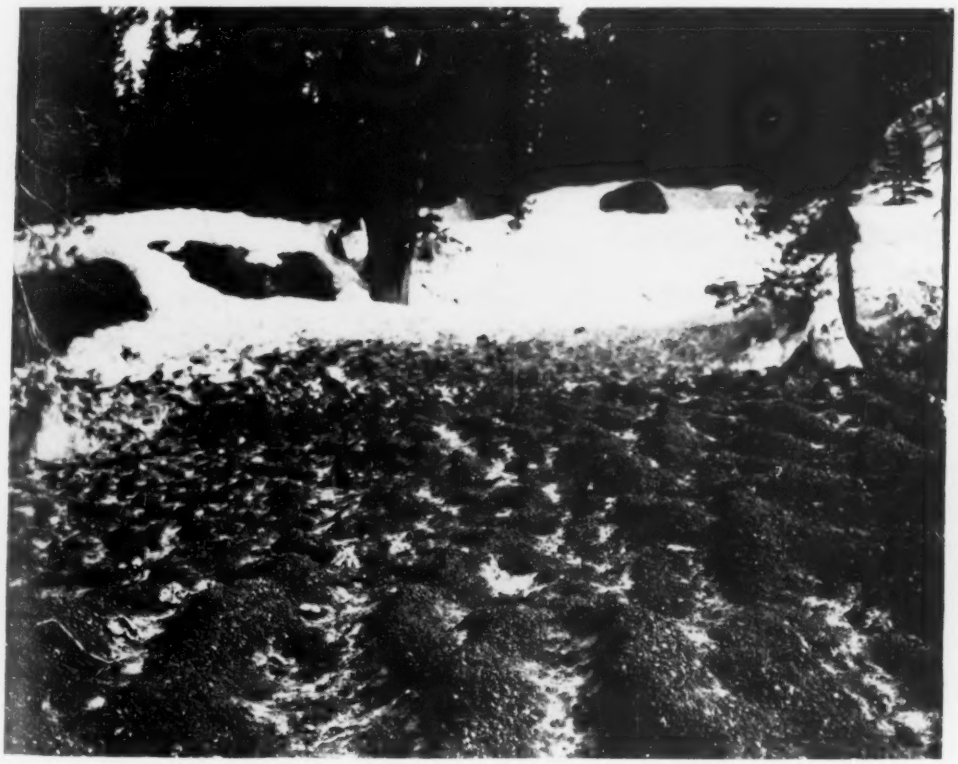
In its hydrological features the glacier or flowing ice is closely associated with snow, which is its original source. It differs only in possessing the additional factor of perennial existence. Otherwise the cycle of the glacier basin resembles that of the more prevalent snow basin.

The glacier basin is one in which the snow accumulation has exceeded the run-off. This excess in turn is due to temperature, which in its turn may be due to latitude or altitude.

Accumulation

Since the upper reaches of a glacier lie in a zone of prevailing cold, the newly fallen snow and condensation there are less subject to continuous melting though exposed to ceaseless evaporation. If the elevation is excessive, the precipitation will be light. This deficiency, however, is offset by drift snow from outside the glacier area and the self-protective depth of drifts that naturally form on wind-swept slopes.

The greatest accumulation is necessarily above the point of equilibrium of the glacier and by its head acts as the driving force of the glacier tongue. The accumulation, which in its turn enters the glacier stream, is renewed seasonally or continuously depending on the nature



Ernie Mack

EFFECT OF CONTINUOUS OPAQUE MATERIAL IN PREVENTING MELTING

ALTHOUGH THE SPARSE MATERIAL ACCELERATES IT. NOTE THE RESULTING WAVELIKE EFFECT.

of the precipitation cycle, but its amount is variable.

Formation of Firn or Névé and Glacier Ice

The snow in glacier basins is both seasonal and perennial, the relative amount of each depending upon the conserving power of the slopes. This is indicated roughly by the relative area of the glacier surface. Yet not all snow that falls on the glacier surface can be considered perennial, for it may melt and run off with other seasonal snow particularly on the lower reaches or fringes of the ice and come out in the glacier stream below.

The distinction between seasonal and perennial snow or firn is as already suggested one of survival, which may carry with it a greater maximum density due to concentration of melt water from persistent freezing. The maximum density of seasonal snow appears to range from 35 to 58 per cent. The density of firn may range from even less to that of glacier ice, 86 to 91 per cent. The initial density, however, is usually nearer 45 per cent.

The physical change of snow to firn is one of crystal growth caused by evaporation and pressure but accelerated by melting. As expressed by Seligman,[10] the delicate plumes of newly fallen snow gradually evaporate and the water vapor condenses upon the residual snow crystals and thus enlarges them. The physical properties of the snow and firn at successive stages have been set forth by him in the following table:

Kind of snow	Specific gravity or density	Grain size (millimeters)	Depth (meters)
Settled snow	0.291	0.1–0.2	0.16
Early firn	0.437	0.3–0.5	1.10
Denser firn	0.463	0.6–1.3	2.70
Old firn (3 yr.)	0.72		14
New ice (6 yr.)	0.80		23
Pinnacle ice	0.92		

The air spaces between the individual flakes of new snow continue as a ramifying network of air channels throughout the firn mass. The extent of the air channels diminishes as the density further increases and the channels become interrupted and sealed into non-communicating chambers. This stage is snow- or glacier-ice, and is distinguished from water-ice by its larger content of imprisoned air, which imparts a grayness to its appearance. This was very obvious on the inland ice of Greenland where vertical fissures had filled with water and frozen into clear blue ice. These appeared to be the source of the blue bands in the icebergs.

Since the air channels in the ice are no longer continuous, ice is not permeable to water except where fissured or traversed by *mühlen* down which surface waters spiral into the depths.

Glacier fields have been classified into alpine, sub-polar, and polar on the basis of temperature, but unfortunately precipitation and altitude modify the simple relationship of latitude, so that heavy melting occurs even at high latitudes where the elevation is low. Only above 2,500 meters in Greenland at latitude 70° N. was melting entirely absent, and slight melting in Antarctica occurs near sea level even above latitude 80° S.

The fundamental factor of pressure separate almost wholly from melting has been observed by Ernst Sorge,[11] at Eismitte, at an altitude of 3,000 meters (9,842 feet), Wegener's central station

[10] Gerald Seligman, The Structure of a Temperate Glacier, *Geog. Jour.*, 97: 295–317, 1941.

[11] Ernst Sorge, The Scientific Results of the Wegener Expedition to Greenland, *Geog. Jour.*, 81: 333–344, 1933; Glaciologische Untersuchungen in Eismitte: Wissenschaftliche Ergebnisse der Deutschen Grönland-Expedition, Alfred Wegener, 1929 and 1930–31, vol. 3.

in Greenland. In 21 annual layers, only at one single spot was an ice crust found, and this was no larger than a hand.

Here the mean annual increase in the inland ice was found to be 31.4 centimeters (12.4 inches) water. The snow cover was penetrated to a vertical depth of 15 meters (49 feet), or through 21 years of snow accumulation. An increase in density was measured from 34 per cent at the surface to 54 per cent at 15 meters or 46.7 per cent average density for practically the entire depth.

Because of lack of cohesion the weight of the snow was unusually effective in increasing its density by expulsion of air, the sound of which appeared to be distinctly audible. At 475–785 centimeters the daily settling averaged 2.7 millimeters; at 695–1005 centimeters, 1.9 millimeters. At 15 meters the rate of increase in density was approaching the vertical. The temperature at 16.6 meters was −28.65° C. (−19.6° F.) and below the influence of seasonal changes. Sorge estimates that a depth of 200 meters will be necessary to compress the snow to 84 per cent, and 1,000 meters to 90 per cent.

The "ice cap" in Central Greenland was measured seismographically by Wegener as 2,500–2,700 meters. At 120 kilometers from the western rim of the inland ice, where the glacier ice is exposed, the ice was approximately 1,700 meters thick. Since the elevation above

Ernie Mack

BARRIERS TO INSOLATION

THIS PICTURE SHOWS THE RELATIVE EFFECTS OF TOWEL, BRANCH AND HEAVY GRAVEL IN PROTECTING SNOW COVER FROM INSOLATION. THE TOWEL IS HUNG UP ON THE SNOW CONE PRODUCED BY ITS SHELTER. THE CONE BEHIND THE FALLEN BRANCH IS SLIGHTLY EXPOSED TO INSOLATION AS COMPARED WITH THE FORMER AND CONSEQUENTLY IS SMALLER. BOTH HAVE BEEN BOMBARDED WITH GRAVEL SINCE THEIR INCEPTION.

sea level at 120 kilometers is approximately 700 meters lower than at Eismitte (400 kilometers), it can be fairly assumed that the glacier ice found at the former point would appear at within 700 meters beneath the surface of the snow at Eismitte, where accumulation is at its full activity.

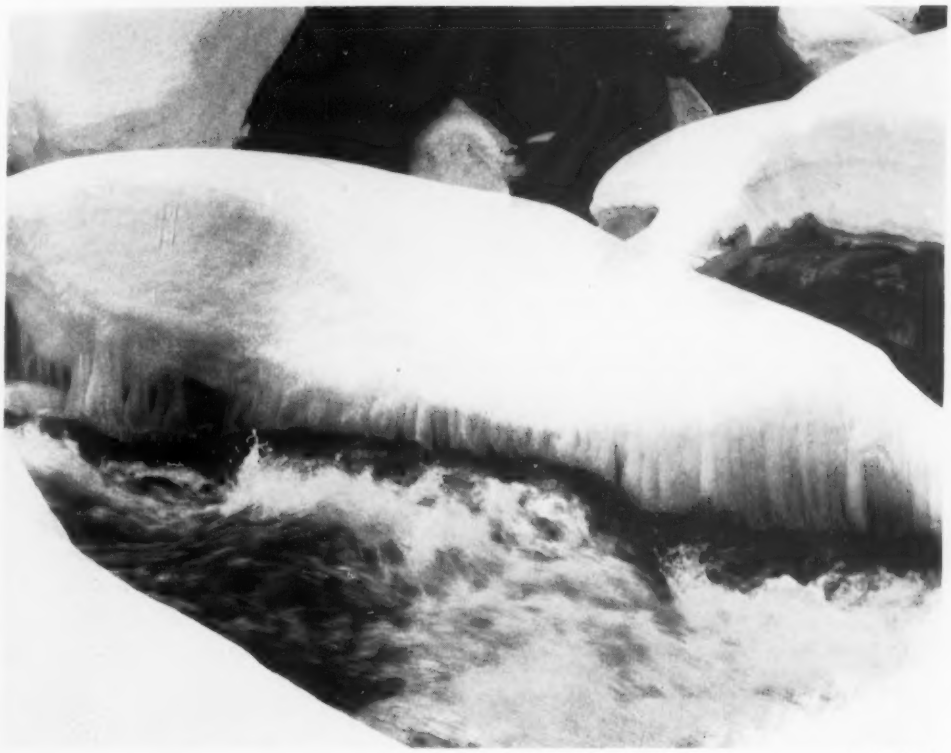
At Jungfraujoch in the Alps in a shaft at 3,640 meters altitude, the firn was found by Seligman to attain a density of 69 per cent at the depth of 20 meters (66 feet) though without further increase in density to 28 meters (92 feet), but in crevasses at 3,330, 3,200, 3,140 meters altitude densities of approximately 86, 84, and 85 per cent were found at depths of 23, 17, and 13 meters respectively. The transitional zone from firn to ice was found at 19, 16, and 11 meters in each, but some of the original firn from which the glacier ice had been formed had disappeared probably by melting, for the firn line occurred at 3,020 meters, immediately below, or at 620 meters lower elevation than the initial shaft.

Seligman remarks that the change from permeable firn to impermeable firn or ice is not accompanied by a marked rise in either the density or the grain size. Furthermore, that at the latitude and altitude of Jungfraujoch zero temperature, Centigrade, ruled below the depth of 15 meters throughout the year. In the case of the open crevasses, situated 300 to 500 meters lower, air temperature has evidently had access to the surface and the depth to the transitional zone of firn to ice has been reduced by melting of the more recent seasonal layers.

Is there a pressure melting point at which the continuous air channels in the

Ernie Mack

BREAKDOWN OF SNOW-CRYSTALS ON SURFACE OF SNOW



Ernie Mack

SNOW AND ICE "LACE" FROM THE SPRAY OF A MOUNTAIN STREAM
SHOWING THE STRATA OF ACCUMULATION AND THEIR WEATHERING.

firn are squeezed out or diked into pockets? This may be indicated by the finding by Oxford University's Arctic expedition under A. R. Glen to North East Land in 1935–36 that "at the depth of 70 feet in the ice cap the temperature was fairly constant at 0.0° C. but at a somewhat greater depth an unfrozen lake was found."[12] Possibly confirming this was the presence of "weeping" at the face of the Greenland inland ice noticed by the author in midwinter of 1927–1928.

Spitzbergen and Iceland, classified by Ahlmann as subpolar, afford ideal fields of glacier study because of low elevation, heavy precipitation, and seasonal temperature influence.

[12] The Glaciology of North East Land, *Geografiska Annaler*, vol. 21; The Oxford University Arctic Expedition, North East Land, 1935–36, *Geog. Jour.*, 90: 289–314, 1937.

The high initial density of the snow at the former, at altitudes of 845–850 meters, as compared with central Greenland, at an altitude of 3,000 meters, is shown in the following table:[13]

	Depth of meas. (centimeters)	Percentage density	Observer
Central Greenland	0 to 238	36.6	Sorge
	0 to 497	39.8	"
	0 to 1,345	46.7	"
Spitzbergen	22 to 235	54.2	"
	0 to 400	57.0	Ahlmann

Sverdrup's investigation showed that

[13] Ernst Sorge, Glaziologische Untersuchungen der Deutschen Spitzbergenexpedition, 1935, *Trans. Internat. Commissions of Snow and of Glaciers*, Edinburgh, 1936, *Bull.* 23, *Internat. Assoc. of Scientific Hydrology*, pp. 733–43.

"the negative winter temperature had disappeared by the beginning of August and that the temperature of the firn was then at melting point throughout. The most important factor in bringing this about was apparently the percolating thaw water. Thaw water, regelating on the firn grains, is, in Ahlmann's opinion, also of decisive importance to the slow growth with depth of the individual firn grains and their grapelike agglomerations.

A striking example of transition from firn to glacier ice was found by Ahlmann in Iceland in 1936, where accumulation and ablation are "inconceivably" large. To quote from his report,[14] "At the end of the accumulation period proper, in the middle of May, the 1935–36 annual layer in the eastern part of Vatnajökull amounted to 700 centimeters of snow, corresponding to about 3,700 millimeters (145.6 inches) of water. . . . In the higher parts of the accumulation area 300–400 centimeters of snow remained of the layer deposited from March, 1934 to the autumn of 1935.

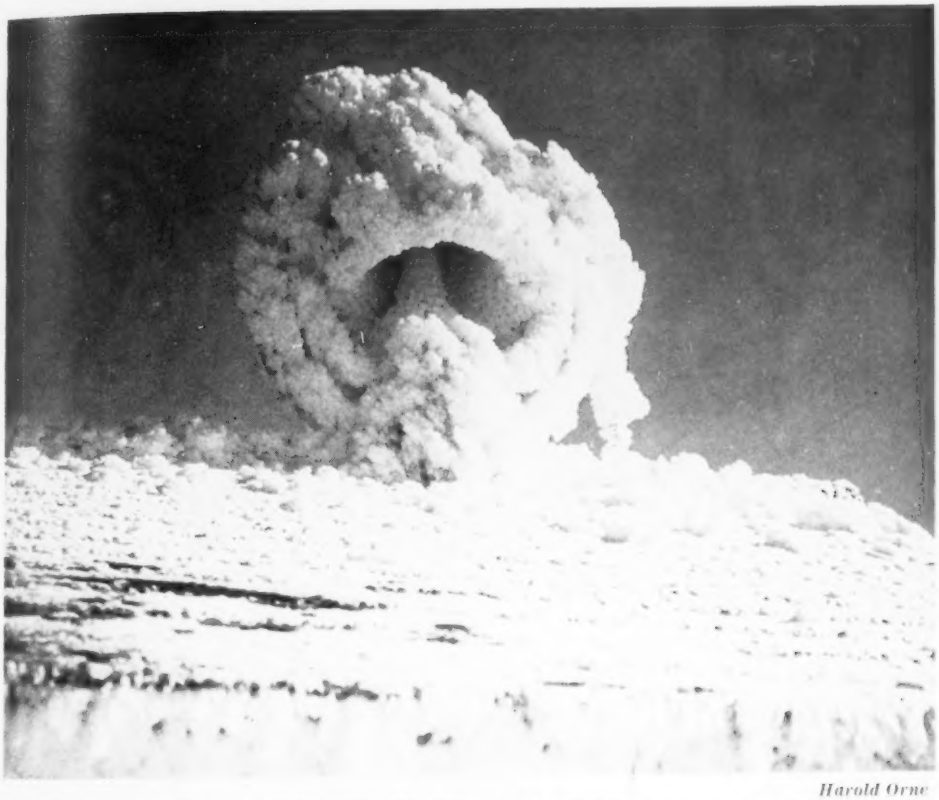
"The 1935–36 annual layer was well stratified by a great many ice crusts and layers of water-logged snow. At a certain depth in the pits, varying with the altitude above sea level, the snow began to assume negative temperature, which fell to $-3°$ C. or $-4°$ C. deeper down. The water-logged snow remained at freezing point throughout the sections, and so did some of the ice crusts.

"At the boundary surface formed in the autumn of 1935 the structure of the material suddenly changed from snow to coarse-grained, porous firn. The recrys-

[14] Hans W: son Ahlmann and Sigurdur Thorarinsson, Vatnajökull, Scientific Results of the Swedish-Icelandic Investigations, 1936–37, *Geografiska Annaler*, 19: 146–229, 1937.

RIPPLE MARKS IN BOTH SNOW AND ICE

CAUSED BY EVAPORATION ACCELERATED BY WARM DOWNSLOPE WINDS ON THE INLAND ICE OF GREENLAND. THE WARMTH CREATES MOISTURE WHICH IS MORE SUSCEPTIBLE TO EVAPORATION THAN FROZEN SNOW OR ICE. THE DEPTH OF THE SNOW IS SHOWN BY THE PIT IN THE LEFT FOREGROUND. SEALED ICE CRACKS, SUCH AS THAT ON THE RIGHT, APPEAR AS BLUE BANDS IN ICEBERGS.



Harold Orne

FROSTED BELL, SUMMIT HOUSE, MT. WASHINGTON, N. H., AT 6,293 FEET

tallization of this firn to glacier ice could also be followed and studied."

Such coarse-grained, porous firn, suggesting hailstones saturated with water, so unconsolidated that the author sank ankle-deep in it, was observed in August, 1928, at 4,500 feet elevation at the edge of Nugssuak "ice cap," Umanak Fjord, Greenland. The impending winter would quickly change the mass to ice aggregate. Seligman proposes the growth of crystal grains in glacier tongues as the subject of his next research and Sorge would obtain firn cores at greater depths in the back of the Greenland ice. Can a snow sampler of thirty times the present length be developed to accomplish this?

The persistence of grain characteristics where not too greatly affected by melt water has been noted by Sorge in Greenland and Spitzbergen and has made possible the identification of seasonal strata by their density and the summer and winter accretions in them. Each region shows its climatic characteristics.

For example, in Greenland the winter snow is denser than the summer snow. For the summer snow is coarse grained and loose and in the higher places of the inland ice is crusted little or not at all. The winter snow, on the other hand, is fine grained and becomes very solidly packed, often through the storms of the winter. This slight excess of density is preserved at least to the depth of 15 meters. In Spitzbergen the summer deposits melt and freeze and are denser than those in winter, when the snow falls

as powder snow of much lighter density. In Iceland rain and snow fall in both summer and winter indiscriminately and make identification difficult.

Condensation vs. Evaporation

In zones where the humidity is high, condensation may exceed evaporation, but in the Arctic, as represented by the Greenland ice, measurements during 1928 and 1929 indicate an evaporation five times as great as condensation for both snow and ice and ten times as great in the case of water.[15]

Rime formation reaches its largest proportions on mountain tops but is restricted in area and because of its porous character is subject to rapid dispersion by evaporation.

Indeed, at high altitudes where cold and aridity prevail, evaporation exceeds melting and results in the spectacular sun pits or *nieve penitente*, perhaps better termed "sun spikes or blades." These have been discussed particularly by François E. Matthes and Humberto Barrera.[16] Sun pits and spikes four feet vertical have been seen on Mauna Kea, Hawaii, on the Tropic of Cancer (23° 27′ N.) at 13,250 feet by Chester K. Wentworth[17] and parallel cases by N. E. Odell at 18,500 feet on Mount Everest[18] at 28° 30′ N. Odell reports that "no melt-water at all was seen either in the cups and pits nor yet trickling away from the snow surfaces. The prevailing diurnal air-temperatures here are well below the freezing point, especially at this time of the year (April)".

Ablation

The active melting of glaciers is controlled largely by altitude and insolation. At high altitudes the ablation takes the form of accelerated evaporation. On the North gap of Mount Everest at 23,000 feet Odell found the midday shade temperature only 29° F. while the sun temperature was 105° F. The visible melting, however, was surprisingly little. "High up on the face of Mount Everest a considerable snowfall will in spring and summer have evaporated into thin air in a few hours without any visible melting."

The seasonal snow cover on the glacier, on the other hand, can delay melting since "much more heat radiation is absorbed by snow-bare ice than by snow. The albedo of wet snow is 64–70 per cent. of ice only 50 per cent." Ahlmann found the greater reflection by the snow "clearly indicated by the ablation curves of the Fourteenth-of-July Glacier, Spitzbergen, for different times of the summer: they bend abruptly at the temporary snow limit."[19]

Therefore, if the snow cover is thick and low, the glacier will be protected, but the retreating seasonal snow or firn line will leave the ice foot exposed to accelerated and uncontrolled melting.

Fortunately, however, when the sky is clear, especially at high altitudes, the surface temperature not exposed to direct sunlight is, on account of radiation, always below that of the neighboring air. The difference is almost as great as

[15] J. E. Church, Meteorological Studies: A. Climate and Evaporation in Alpine and Arctic Zones, Report of the Greenland Expeditions of the University of Michigan, Part II, pp. 7–59.

[16] (a) François E. Matthes, Ablation of Snow Fields at High Altitudes by Radiant Solar Heat, *Am. Geophys. Union Trans.*: 380–85, 1934; (b) Humberto Barrera, A Study of the "*nieve penitente*" of the Chilean Andes, Trans. Internat. Commissions of Snow and Glaciers, Edinburgh, 1936, Bull. 23, Internat. Assoc. of Scientific Hydrology, pp. 587–622.

[17] C. A. Wentworth, Ablation of Snow under the Vertical Sun in Hawaii, *Am. Jour. of Science*, 238: 112–16, 1940.

[18] N. E. Odell, Ablation at High Altitudes and under High Solar Incidence, *Am. Jour. of Science*, 239: 379–82, 1941.

[19] Hans W:son Ahlmann and Sigurdur Thorarinsson, The Vatnajökull Glacier, Preliminary Report of the Work of the Swedish-Icelandic Investigations 1936–1937, *Geog. Rev.*, 28: 417, 1938.

U. S. Antarctic Service

THE ANTARCTIC SNOW—PRESENT LURE OF THE SNOW SCIENTIST

A SNOW CRUISER WHICH IS BERTHED AT WEST BASE, ANTARCTICA, VIEWED FROM AN AIRPLANE AT AN ALTITUDE OF ONE HUNDRED FEET.

at night, when the surface temperature may be five, ten, or even fifteen degrees C. below the temperature of the air (Dorsey).[20] Consequently the crispness that instantly occurs on the snow fields at sunset and the cessation of melting in the Arctic as the sun slightly declines.

The Regime of Glacier Streams

The regime of glacier streams can be best presented and understood against the background of rain- and snow-fed streams. Secondo Alfieri has done pioneer work in this field.[21]

In the Italian Alps and Appenines he has selected five basins, three of which are snow and glacier, one snow, and one mostly rain. The comparison covers seven years, 1931–1937. These glacier basins are somewhat higher than those of the Central Sierra Nevada, and are slightly farther north. Their peak flow should therefore be later.

The essential characteristics of these

[20] N. Ernest Dorsey, Properties of Ordinary Water-substance in All its Phases: Water-vapor, Water, and all the Ices, p. 492.

[21] Secondo Alfieri, Influenza della Neve e del Ghiaccio sulla Portata dei Corsi d' Aqua: Internat. Com. of Snow and Glaciers, Washington, 1939 (awaiting publication).

Virgil D. Sisson, Kindness of Chester Versteeg

DESICCATED SNOWFIELD

WITH SUN PITS ALMOST ENTIRELY VANISHED, LEAVING THE SUN BLADES STANDING ALONE. THE LOCATION OF THIS SCENE IS IN THE CENTRAL HIGH SIERRA AT 13,000 FEET ON THE NORTHERN APPROACH TO "THE SPECTATOR," ON THE SIERRA CREST AT THE HEAD OF LAMARCK CREEK NEAR PIUTE PASS WEST OF BISHOP, CALIFORNIA. PHOTOGRAPHED AUGUST 3.

C. A. John Hendry

UNCONSOLIDATED FIRN AT EDGE OF NUGSSUAK "ICE-CAP"

IN ARCTIC MID-SUMMER (AUGUST) AT 4,500 FEET, UMANAK FJORD, GREENLAND. A CHARACTERISTIC OF NATURE'S PERSISTENT ADJUSTMENT WAS A CLUMP OF ICELAND POPPIES MORE DELICATE IN STEM AND COLOR THAN THEIR CALIFORNIA COUNTERPART, BLOOMING AT THE EDGE OF THIS PERENNIAL SNOW IN GRAVEL SATURATED WITH ICE WATER. HERE WAS NATURE EMERGING FROM ITS ICE AGE.

TABLE I

HYDROLOGIC CHARACTERISTICS OF ALPINE BASINS

Stream and gaging station	Location	Area of basin (Square kilometers)	Mean altitude of basin (meters)	Glacier surface (Square kilometers)	Mean altitude of glacier (meters)	Proportion of glacier to basin (per cent)	Coefficient of annual runoff to precipitation (Average, 1931–1937)
—Glacier—							
Lys a D'Ejola	Alps Dora Baltea (Monte Rosa)	30.4	3,112	14.4	3,580	47	1.39X
Frodolfo ai Forni	Adda Superiore	48.5	2,800	22.8	3,200	47	2.04X
Rutor a Promise	Dora Baltea	49.8	2,616	13.8	2,900	28	1.31X
—Snow—							
Corsaglia alla Presa Centrale Molline	Maritime Alps	88.5	1,530	Generally snow at higher altitudes remains on ground for several months.			0.82X
—Rain—							
Reno a Pracchia	Northern Appenines	40.9	890	Limited amount of winter snow but melts quickly.			

five basins are shown in the accompanying table.

The heavy melting of the glaciers that has been in regression for several years naturally increases the coefficient of runoff with reference to annual precipitation. But Alfieri's reference to non-glacier basins in which on certain years the runoff equalled or exceeded the precipitation indicates lack of sufficient precipitation data, probably at higher altitudes.[22]

However, even if the coefficient of runoff is overlarge, it still represents the relative effect of ice, snow, and rain on runoff.

Of the glacier basins, the Frodolfo seems to have the most favorable altitude for melting of its ice reserve. The Lys is too high and the Rutor has too small a glacier for its area. The Corsaglia, though having no ice reserve, maintains an extremely high coefficient for snow. The Reno, owing to losses of precipitation in the frequent repriming of its soil, has the lowest coefficient of all.

The monthly and seasonal phases of precipitation and runoff can most clearly be shown in percentages of the annual (Table II).

The precipitation is quite evenly distributed throughout the year with slight excess in the summer months. This, however, has little effect on the regimen of the ice- and snow-fed streams, for their phases are chiefly due to temperature acting upon accumulation.

The glacier streams because of the low temperature at their high altitude and reserves of ice have their major runoff during June–September. The lower snow-fed basin, Corsaglia, has its major runoff in March–June, which ends in the exhaustion of the seasonal storage of

[22] The Rhone Glacier Basin (24.19 sq. km.) has 10 precipitation stations; the Montreux Basin (13 sq. km.), 50 during 1931–1938; Lake Davos Basin (9.47 sq. km.), 16. All should thus be ideal for snow and runoff studies.

TABLE II

MEAN PRECIPITATION AND RUNOFF, MONTHLY PERCENTAGE OF ANNUAL

	Annual	Jan.	Feb.	Mch.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
Glacier—Lys a D'Ejola (Sq. km 30.4; ice 47%; mean altitude 3,112 meters)														
Precipitation	1,260 mm	4.3	5.5	8.5	8.5	12.5	8.8	6.7	7.6	10.6	8.2	10.6	8.3	
Runoff	55.5*	0.6	0.5	0.5	1.9	9.0	*19.0*	*23.5*	*23.3*	*13.7*	5.6	1.6	0.8	Major runoff 79.5%
Frodolfo ai Forni (Sq. km 48.5; ice 47%; mean altitude 2,800 meters)														
Precipitation	894 mm	5.1	4.7	6.3	6.9	1.0	10.6	12.5	11.7	10.6	10.3	6.5	4.7	
Runoff	57.9*	0.8	0.6	0.5	0.7	4.0	*18.2*	*23.4*	*23.4*	*15.0*	5.6	1.7	1.0	Major runoff 85.0%
Rutor a Promise (Sq. km 49.8; ice 28%; mean altitude 2,616 meters)														
Precipitation	1,484 mm	7.6	6.0	10.2	7.5	8.0	7.7	8.2	9.9	11.5	6.9	7.5	9.0	
Runoff	61.8*	1.0	0.8	0.8	1.9	9.7	*21.8*	*25.2*	*19.4*	*11.8*	4.4	1.9	1.3	Major runoff 78.2% (5 mos. 87.9%)
Snow—Corsaglia alla Presa della Centrale Molline (Sq. km 88.5; mean altitude 1,530 meters)														
Precipitation	1,536 mm	6.0	4.3	12.2	8.3	11.8	6.8	5.5	6.4	7.4	8.9	14.6	7.8	
Runoff	40.1*	3.3	3.6	*7.3*	*15.2*	*25.4*	*13.1*	6.4	3.1	3.8	6.7	7.1	4.8	Major runoff 61.0%
Rain mostly—Reno a Pracchia (Sq. km 40.9; mean altitude 890 meters)														
Precipitation	2,189 mm	7.9	7.9	11.9	8.2	8.5	8.5	2.4	3.2	4.9	15.0	13.7	10.0	
Runoff	51.9*	*9.9*	*9.7*	*17.6*	*8.6*	*7.9*	*5.6*	1.7	0.8	1.0	*9.8*	*15.5*	*12.1*	Min. runoff 3 mos. 3.5%

* Liters per second per square kilometer.

snow. The excess of 20 per cent in the major runoff of the former three (80.9 per cent) over the latter (61.0 per cent) indicates the present wastage of ice reserves. If annual replacement were equal to ablation, the major runoff should be more comparable with that of the snow, except that the runoff will last longer.[23]

The rain basin, Reno, has a continuous runoff, lagging apparently behind the rainfall except that its dry season in July–September synchronizes with the three months of minimum precipitation.

The forecasting of the runoff of snow and glacier streams requires merely a normal or standard of comparison of the annual snow cover and the ablation of the ice. As early as 1914 Dr. Alfred de Quervain and Dr. R. Billwiller began sampling the annual reserve of snow in the *névé* of glaciers.[24] This system should be extended to the entire water-

[23] The amount and duration of melting is proportional to altitude. For example, during 1930–1937 the average amount and period of melting of the glacier of Bors (3,050 m.) were 189 cm. (6.2 ft.) and 2 mos.; of the Lys at Salzen (2,350 m.), 790 cm. (25.9 ft.) and 5 mos.

[24] J. E. Church, Present Methods of Glacier Study in the Swiss Alps, *Mo. Weather Rev.*, 52: 264–66, 1924.

shed both non-glacier and glacier in the same manner as applied to snow basins. Because of the ruggedness of the terrain the percentage method should preferably be used. Where possible, stream-gaging stations should be established particularly in the non-glacier areas as a check on the accuracy of the snow-surveys. Precipitation stations would be a valuable supplement.

Since fluctuations in temperature can not be forecast, estimates should be confined to the total major runoff rather than to peak flows.

Through the pioneer efforts of Dr. Otto Lütschg-Lötscher[25] photogrammetric surveys of the fluctuation of glaciers in volume now provide an accurate method of determining the seasonal water content of the ice as of a reservoir. The net relationship between annual accumulation and dissipation can thus readily be determined. Charts of the Upper Saas Valley, Monte Rosa Massif, and Upper Grindelwald Glacier in the Jungfrau Group make these areas highly desirable initial points in the development of snow-surveying in the Alps.

Glacier Flow and Icebergs

The alluring field of glacier flow and iceberg migration has been opened wide by Gerald Seligman, Dr. Max Demorest, and Commander Edward H. Smith of the Ice Patrol and provides a further chapter on the romance of snow and ice.

Max and Becky Demorest have studied ice flow in its mountain bed and placed glacier ice under laboratory compression. Commander Smith has brought ice from the Greenland sea for them to study, and has begun a census of icebergs enroute from their parent glaciers to their melting point in the Atlantic sea-lanes the better to forecast their frequency.

Now Max lies dead in the distant North in service of his science and his country. His memorial is the hearty acceptance of his discoveries by François E. Matthes,[26] interpreter of glaciology, and the bestowal of a Guggenheim and other fellowships to finance his plans still scarcely within the threshold of achievement.

But he has the frozen glaciers to share his quiet. No better spot for his eager spirit.

On the Back of the Great Ice[27]

"And Abraham sat in the door of his tent and gazed down upon the plains of Jordan." Thus we sit tonight on the great ice 1,500 feet in air and gaze down upon the panorama of Inner Greenland stretching in haze and luminous sunset color toward the distant sea. It might well be out West on the rim of Death Valley, save that here we look down a broad canyon with a spreading, winding river dazzling in the sun like silver, and in a parallel valley upon a large lake rivaling Taserssuak in size. Beyond multitudinous hills rises the slope of Pingo looking like some Northern Ararat. Beyond the purple haze rides a long thin band of clouds. The rolling sea of ice is in front.

[25] Dr. h.c. Otto Lütschg, Zum Wasserhaushalt des Schweizer Hochgebirges: Presidential Address Internat. Assoc. Sci. Hydrology, Washington, 1939 (awaiting publication). Pre-publication copies available.

[26] François E. Matthes, Glaciers, Physics of the Earth—IX, Hydrology, pp. 149–219, National Research Council.

[27] From the author's diary.

PHARMACOLOGY OF THE SULFONAMIDE DRUGS

By Dr. SANFORD M. ROSENTHAL

SENIOR PHARMACOLOGIST, DIVISION OF CHEMOTHERAPY, NATIONAL INSTITUTE OF HEALTH

THERE are few drugs with systemic effects that are being so widely used and in such large doses as the sulfonamides. A proper understanding of their behavior in the body is especially necessary for their safe and successful use. Laboratory experience has emphasized the wide variations met when going from one species of animal or bacterium to another; and what is equally important, the considerable differences in the toxic or therapeutic response met when studying large groups of individuals or several strains of the same organism.

Excellent reviews of this subject have recently been made by Marshall[1] and by Goodman and Gilman[2] and no complete survey will be attempted in this paper.

ABSORPTION AND EXCRETION

Absorption from the stomach is negligible for all drugs of this group. Sulfanilamide is readily absorbed throughout the remainder of the alimentary canal, as well as from the serous cavities and from open wounds. When given by mouth, water accelerates absorption, presumably by hastening the passage from the stomach to the intestines. Absorption of sulfanilamide is greatest in the first four to six hours and is practically complete in twenty-four hours. As proof of this only traces appear in the stools and 70 to 95 per cent. is recovered in the urine, mostly within twelve hours. With normal kidney function, excretion is complete in two to three days.

The sulfanilamide derivatives in current use are absorbed more slowly and with less regularity. This is due in part to their poor solubility. Sulfapyridine in particular is slowly, irregularly and poorly absorbed. As much as 20 per cent. may escape absorption and appear in the stools. Absorption from the colon and rectum is slight.

Sulfathiazol is better absorbed and a smaller percentage (0 to 10 per cent.) appears in the stools. Published reports by Feinstone and others on sulfadiazine indicate a higher and more sustained blood level, with slower excretion. In man approximately two thirds can be recovered in the urine in forty-eight hours. Studies of fecal excretion are lacking.

Sulfaguanidine was found by Marshall to be absorbed only from the small intestine. Excretion in the urine varies from 5 to 70 per cent. Only a limited capacity for absorption exists; hence, with increasing doses absorption does not increase proportionally. By giving large doses it is thus possible to get high concentrations throughout the alimentary tract, and correspondingly low concentrations in the blood.

The most recent addition to the series of sulfonamides designed for intestinal disinfection is succinyl sulfathiazol. Experimental evidence indicates that less than 5 per cent. of this drug is absorbed, and it has not been possible to produce pathological changes in rats or monkeys from large doses given orally for one month.

These poorly absorbed sulfonamides can suppress the normal coliform bacterial flora of the intestines to an extent that could not be previously accomplished. Elvehjem and co-workers demonstrated an interference with the

[1] E. K. Marshall, Jr., *Annual Rev. Physiol.*, 3: 643, 1941.

[2] L. Goodman and A. Gilman, "The Pharmacological Basis of Therapeutics." New York: The Macmillan Company.

growth of rats which they interpreted as a deficiency state due to suppression of a growth factor normally synthesized by these intestinal bacteria. Daft, Sebrell and co-workers have produced some characteristic pathological changes when sulfaguanidine was administered to animals upon a diet deficient in vitamin B complex. The importance to the clinic of these significant experiments remains to be established.

Distribution

Sulfanilamide is notable for its distribution throughout all the tissues and body fluids in concentrations closely approaching that in the blood. Until recently it was believed that the sulfonamides existed in the body in a free, diffusible state. However, Bernard Davis has shown that they attach themselves to the plasma (and presumably tissue) proteins; the extent of binding varies from 5 per cent. with sulfanilamide to 70 per cent., with sulfathiazol. Intimately related to this phenomenon is the problem of ionization of the sulfonamides. It has recently been shown by C. L. Fox, F. Schmelkes and others that sulfanilamide at the pH of the body ionizes very little, while some of the more active sulfonamides dissociate to a high degree. Both binding and ionization are important influences upon the behavior of drugs in the body, and these effects throw light upon certain variations in the distribution of sulfonamide compounds, such as the lower concentrations of sulfathiazol attained in the spinal fluid.

Further remarkable characteristics of the sulfonamides are their relative lack of irritating effects when applied locally, and the high tolerance of the tissues to them without apparent harm to the defense mechanisms of the body.

Fate in the Body

Surprisingly few of the organic chemicals which are absorbed escape some change during their sojourn in the body. With the sulfonamides this consists chiefly of the introduction of an acetic group in the free amino radical. It is not determined whether this change is an attempt on the part of the body to render the compound less toxic or whether it is simply following a process which is physiological for certain metabolites and into which pattern certain foreign substances such as the sulfonamides seem to fit. Actually the acetylated sulfonamides are more toxic to the host, and furthermore they are practically devoid of therapeutic activity, so that this change is quite undesirable from the standpoint of drug therapy.

The extent of acetylation varies widely with the compound, with the species and to a lesser extent with the individual. With sulfanilamide there is little or no acetylation in the dog and frog, while it occurs to 50 per cent. or more in the rabbit and man. From 25 to 75 per cent. of the sulfanilamide administered to man is acetylated.

Sulfapyridine shares this objection to as great or to a greater degree. In man from 15 to 75 per cent. may be acetylated. Sulfathiazol is conjugated to a less extent and in man reported values are up to 30 per cent. Sulfadiazine shows very little conjugation in the blood, but 10 to 60 per cent. of the drug in the urine is acetylated. The excretion by the kidney of the N-4-acetyl derivatives is more rapid than that of the free compounds. Acetyl sulfonamides, therefore, leave the blood faster and the amount of acetylation in the blood may not be a true index of the total acetylation which will be found in the urinary output.

Acetylation of the amino group is a disadvantage for several reasons. Such acetyl derivatives are inactive therapeutically; they are of increased toxicity; the process of acetylation imposes a physiologic burden on the body; and finally the acetyl derivatives of many compounds are sufficiently insoluble to

be precipitated in crystalline form in the urinary tract to the extent that kidney damages and stone formation may result.

Because of technical difficulties, knowledge of the fate of these compounds has been limited largely to the free amino group. Oxidation products of this group are known to be of greatly increased toxicity and of possible interest in mechanism of action. In the test-tube sulfanilamide can be broken down by chemical means and by ultra-violet light (Fox, Shaffer, Rosenthal), extensive change occurring at both ends of the molecule. Our information will be incomplete until it is determined to what extent such changes occur in the body. Scudi has shown that sulfapyridine is excreted in part as a hydroxy derivative.

Mechanism of Action

It is generally agreed that the action of the sulfonamides is primarily upon the organisms causing disease. In the test-tube, under conditions favorable for cultivation, this action is not impressive, and is chiefly an inhibition of growth. While there is a general correlation between effect in the test-tube and in the body, many exceptions are encountered when studying different compounds and different organisms. As an example may be cited the susceptibility of the alpha streptococci (viridans) in the test-tube and their resistance to chemotherapy in the body.

Such variations may be made clear with increasing knowledge. It may be reasonably assumed from present evidence that the sulfonamides act by inhibiting the growth of bacteria in the body so that the natural defense mechanisms may successfully cope with the infection. The importance of the natural defenses in the success of chemotherapy is thus sharply emphasized.

The first attempt to explain bacterial inhibition was made by Mayer on a basis of oxidation of the amino group to a hydroxylamine. This product is much more active in the test-tube, but highly unstable. Mellon and coworkers advanced this theory by virtue of the inhibiting effects of these oxidation products on catalase and perhaps other enzymes which would lead to the accumulation of toxic metabolites, specifically hydrogen peroxide in the bacterial cell.

The inhibition of bacterial growth on a basis of interference with the metabolic requirements was proposed by Lockwood, who demonstrated that peptones could antagonize the bacteriostasis of sulfanilamide. English workers established the occurrence of antisulfanilamide factors in many cell extracts, cumulating in the demonstration by Woods[3] that p-aminobenzoic acid or a closely related compound was present in such extracts and that traces of it could neutralize sulfonamide bacteriostasis. This antagonism is specific, and we have found no effect of p-aminobenzoic acid on the various antiseptics, such as formalin, peroxides, mercury compounds or upon the action of antiserum.

Woods has postulated the role of p-aminobenzoic acid or a derivative as that of an essential metabolite for plant and perhaps animal organisms, a vitamin for bacteria, which sulfanilamide by virtue of its similar chemical structure can replace in the enzyme system and thereby interfere with its utilization.

This postulate satisfied many of the puzzling features of the problem, such as the inactivity of the isomers of sulfanilamide, the lag observed in the bacteriostatic action, the inhibition of growth rather than the killing effect of the drug on bacteria.

More information is needed regarding the presence and function of p-aminobenzoic acid both in the bacterial cell and in the animal organisms, and the reasons for the high tolerance of animal

[3] D. D. Woods, *Brit. Jour. Exptl. Path.*, 21: 74, 1940.

tissue to the sulfonamide drugs. It remains to be seen whether the immunity of certain bacteria to sulfonamides is related to their aminobenzoic acid metabolism. The postulate is of immense practical value as a working hypothesis for the development of new compounds, as well as for opening new fields of investigation.

Recent work has brought out that the degree of activity of a sulfonamide compound may be fundamentally related to its physical characteristics. Mention has been made that the sulfonamides vary in the extent to which they are bound to body proteins and the extent to which they are ionized in the body fluids. The several investigators responsible for these observations have related them to antibacterial action. The *degree* of therapeutic action has been shown to be a function of that portion of the drug bound to the proteins, and likewise to that portion of the drug which is ionized. A correlation has been established between acidic dissociation constants and antibacterial action that may prove of value as a guide to the chemist in his search for drugs with greater curative action.

The ability of the sulfonamides to counteract certain bacterial toxins in the body has been established by Levaditi, by Carpenter and others. While it has not been possible to relate this to curative action, it is highly significant as a starting point towards drugs with antitoxic action.

Toxicity

The large doses and sustained treatment required for the sulfonamides make it predictable that toxic effects will be the rule. Are the toxic effects so closely related to therapeutic action that it will be impossible to avoid them? The answer is at present unknown, but the sketchy evidence at hand will be presented.

It appears probable, though not proved, that the more important toxic effects are related to the free amino group, which unfortunately seems essential to therapeutic activity. Aromatic amino compounds without the sulfonamide group, such as analine or acetanilid, bring about in man toxic reactions very similar to sulfanilamide, such as cyanosis, anemia, agranulocytosis, dermatitis, drug fever, nervous symptoms and liver damage. The methemoglobin formation and perhaps other of the toxic actions of acetanilid are believed to be due to oxidation products which are formed in the body. It is probable, though not established, that similar oxidation products are involved in the action of sulfanilamide on the blood pigments. At any rate, it would seem unwise to administer drugs containing an aromatic amino group (acetanilid, phenacetin, aminopyrine) to patients under sulfonamide therapy. Sulfur in the diet may increase sulfhemoglobin formation (Richardson), but this pigment is not an important factor in the cyanosis in man.

Anemia can be produced by a variety of benzol derivatives including benzol itself. Methods for quantitative study of this effect in the laboratory have recently been developed by Richardson, so that knowledge can now be obtained of the relation of chemical structure to this action. M. I. Smith of this institute has recently shown that in rats the anemia from sulfanilamide is more marked on a low protein diet; higher concentrations of the drug in the blood were present under these conditions. Fox and Ottenberg have found larger amounts of the newly described methemalbumin in the blood of patients with hemolytic anemia from sulfonamides.

The compounds in use, other than sulfanilamide, can depress renal function; this is not due entirely to the acetyl derivative, since it can occur in the dog where acetylation does not occur.

The nausea and vomiting is due, in part at least, to central action, since Sadusk could bring it about in dogs by the intravenous injection of sodium sulfapyridine.

So little is known of the mechanism of production of other toxic symptoms that it is not profitable to discuss them. It is believed that the practice of grouping many symptoms under the category of idiosyncrasy is erroneous and should be limited to such effects as angioneurotic edema or other rarely occurring anaphylactoid phenomena. The majority of toxic effects are expressions of disturbances that occur frequently, but differ widely in their severity.

Little is known concerning the role of the sulfonamide group to toxicity. The acute toxicity of sulfanilamide in laboratory animals is characterized by nervous symptoms, spasticity and ataxia, and by dyspnoea. The compound benzene sulfonamide (with no amino group) is several times as toxic to mice as sulfanilamide and brings about the same picture of intoxication.[4] The toxicity of acetyl sulfanilamide is similar to that of benzene sulfonamide, and can therefore be definitely related to the sulfonamide group.

Another effect of the sulfonamide group demonstrated by Mann and Keilin and by Locke, Main and Mellon is the inhibition of the enzyme carbonic anhydrase. This enzyme accelerates the conversion in the body of carbon dioxide into bicarbonates. By inhibiting this action the sulfonamide group brings about the so-called acidosis. The derivatives substituted in the sulfonamide group (sulfapyridine, sulfathiazol) do not show this inhibition and would not be expected to cause the acidosis. Here is an example of a toxic effect that can be abolished without loss of therapeutic action by changing the molecule. Finally it should be noted that cumulative toxicity of the sulfonamides can be demonstrated in the laboratory. Emaciation is a prominent feature and death can not be adequately explained by the lesions found at autopsy.

[4] Unpublished data.

Relation of Chemical Structure to Therapeutic Action

The development of new chemotherapeutic compounds of this class has become one of the most active fields of research. Only a few generalizations can be made concerning the several thousand compounds already described.

They are all benzene derivatives with a free or potentially free amino group in the para position to a radical which may contain sulfur, arsenic, carbon or phosphorus (Rosenthal and Bauer). Accordingly, while many changes or replacements can be made in the sulfonamide group, the amino group seems essential.

It is of interest that while some derivatives of sulfanilamide are more active against the pneumococcus and certain other organisms, none are appreciably more active against the streptococcus. It is also of interest that the sulfones, which are several times as active as sulfanilamide against the streptococcus, are only slightly more active against the pneumococcus.

Reports also indicate increased activity of the sulfones against experimental malaria (Coggeshall) and experimental tuberculosis (Feldman and Hinshaw, Smith, Emmart and Westfall). Replacement of sulfur by carbon (in p-nitrobenzoic acid) gives slight antibacterial action, and also some effect on trypanosomes. There is evidence, therefore, that specific action against certain infections can be shown.

Compounds with promising degrees of activity against streptococci have been obtained where sulfur is replaced by arsenic or phosphorus, although the former are very toxic.

These illustrations demonstrate the wide chemical approach to the problem,

and exploration of the possibilities has really just begun.

The activity of a compound is highly influenced by its behavior in the body. Many of the changes in activity reported for new compounds are undoubtedly due to such differences rather than to differences in true therapeutic activity.

Experimental Therapy

Greatly discordant results have been obtained in testing drugs upon experimental infections, and it is small wonder that in the clinic no uniformity should occur. Some factors contributing to this confusion will be enumerated.

Differences in absorption, conjugation or excretion are important, and it is to the work of Marshall[5] that a more quantitative basis has been established. Rather than the amount of drug given, he has correlated activity to the concentration of free drug in the blood. Sustained blood concentrations were accomplished by incorporating the drug in the diet of laboratory animals, after the technique of Bieter. It may be pointed out that the activity of sulfanilamide against a streptococcal infection in mice is increased more than four times if it is administered throughout twenty-four hours (in the diet) as compared to one daily dose by mouth.

The relation of diet to therapeutic response was brought out in some studies we made on mice. The blood concentration and therapeutic response was increased approximately three times on a low protein diet (6 per cent.) as compared to a normal diet. The work of M. I. Smith had previously shown that an increase in toxicity also occurs under these conditions.

Most laboratory information has been based on prophylactic therapy in the sense that medication is begun at the time of inoculation or shortly after. Delay in therapy or the use of heavy infections greatly diminishes the results. Likewise therapy of brief duration may be associated with a high percentage of delayed deaths.

Subcurative therapy may lead to the development of resistance or "fastness" to the drug by the organisms. More important is the occurrence of naturally resistant strains, about which nothing is known. Likewise the resistance to therapy of related groups of organisms, such as the alpha streptococci (viridans), is totally unexplained. Many of these naturally resistant organisms are susceptible in the test-tube.

It is of great importance to the clinician to know whether an unsatisfactory response is due to an overwhelming infection, to a resistant organism, to inadequate therapy, to difficulties in absorption or acetylation or to toxicity of the drug.

Answers to some of these problems and many new advances are to be expected from continued research in this new field.

[5] E. K. Marshall, Jr., *Bull. N. Y. Acad. Med.*, 16: 723, 1940.

THE GERMAN "RACE"

By Dr. A. HRDLIČKA

FORMERLY CURATOR OF PHYSICAL ANTHROPOLOGY, U. S. NATIONAL MUSEUM

JUST as in the case of other European nations, the origins of the Germans are lost in prehistory. The generally accepted notion is that their ancestors were derived from the Scandinavian countries. But this is probably erroneous. The large region that the Romans in the latter part of the first century B.C. found occupied by the German tribes had had, up to a certain latitude, a paleolithic, and throughout its habitable extent, a neolithic population. There is no reason to believe that the latter had completely disappeared, leaving the parts open to northern immigration.

It may justifiably be assumed that the early Germans were the descendants of the neolithic and bronze age populations of the region, with adjuncts in the course of time from what later became Denmark and from the southernmost parts of the Scandinavian peninsula. That they at any time could have constituted a "pure race" or type is highly improbable, and is gainsaid by the differences seen in the skeletal remains from the region.

There is no recorded knowledge of the new complex of people until about 350 B.C., when the first scanty information concerning them is brought south by Pytheas, a Greek trader of Massilia.

Between 113 and 102 B.C. the Germanic tribes of Teutoni, under chief Teutobod, and Cimbri, carry out a mass trek southward with their families, wagons and animals, over the Rhinelands and through what is now France, towards Italy, but are almost annihilated at Aquae Sextiae (now Aix-les-Bains) by the Gallo-Romans under Marius and disappear from the stage.

The terms *Germania* and *Germani* appear first in a writing of the Greek historian Posidonius, in 80 B.C. Their derivation is uncertain. It is believed that they were first employed by the Gauls, for their non-gallic neighbors beyond the Rhine. It was not used by the earlier Germans, and to this day is among them of secondary nature. It was definitely established by Caesar, in his classic "De bello Gallico." The terms *Deutsch* and *Deutschland*, by which the Germans call themselves and their country, are derived (Brockhaus) from *diot*, the People, and came into use much later, appearing first towards the end of the ninth century in Italy, and rarely in Germany until the end of the thirteenth century. The term *Teutons*, as applied to all the Germans, is also late, beginning to appear from about the middle of the tenth century.

For the first three centuries of our era —centuries of direct contacts of the Romans with the Germans—information about the latter is limited to Roman and Greek historians, the most prominent among whom are Strabo,[1] Pliny the Elder,[2] Tacitus[3] and Ptolemy.[4] But only a part of this information is first hand, the rest being derived from the reports of traders and soldiers; and none is exhaustive.

It is known then, however, that the Germans are a relatively large group; that they consist of numerous independently warlike tribes, which though apparented in blood, differ more or less in language and in other respects; and that these tribes occupy most of the large region bounded by the Rhine, the Dan-

[1] Geography; around the beginning of the Christian era.

[2] Bella Germaniae; Natural History, third quarter of first century A.D.

[3] Germania, 98 A.D.

[4] Geography; latter half of second century A.D.

ube and the northern seas. The eastern boundary alone, and that both geographically and ethnically, was indefinite, the Germans impinging there on an even much less known people, the "Venedi" or, as later known, "Sclaveni," or Slavs.

The Roman wars and contacts with the Germans lasted from the middle of the first century B.C. to the fourth century A.D. These contacts were especially close in the Rhine provinces, where the Romans founded a line of cities and where they doubtless had left among both the Gauls and the Germans some blood admixture. The Gauls and Germans, alone, bordering since old on each other and overlapping in places, must also have mixed and that apparently to a considerable extent, somatic evidences of which exist to this day in these parts, as will be shown later.

The German tribes were sturdy and prolific; the people, except along the seas, were essentially agricultural; but large parts of the territory they occupied were covered with forests or sands that gave little sustenance and had harsh climate. The results were, as already seen with the Teutons and Cimbri, mass movements in all promising directions, particularly towards the warmer and richer lands in the south; and as all these regions were occupied, the German spreads became for the most part forcible invasions.

These invasions began, so far as recorded, towards the end of the second century B.C. by the already mentioned Teutons and Cimbri, are followed in the first half of the second century A.D., in the east, by that of the Vandals, though there is doubt as to the Germanic affiliation of this group; towards the end of the second century by that of the Goths, who were, it seems, of Scandinavian derivation; and in the fourth to fifth centuries, when Roman domination weakened, by those of the western coast tribes (Angli, Saxons, etc.) into Britain, the Franks into Gaul (present Belgium and France), the Burgundians[5] into Gaul, the Alemans[6] and Suevi (Swabians) into Switzerland, the Langobards towards the middle Danube and finally Italy. None of these offshoots return to their former abodes; but some stay in parts that eventually become southern Germany and there admix with the older Gallic or Keltic populations.

To this time there is no union or even a close association of the numerous Germanic tribes; but by the fifth century the Franks have established their dominion in "Gallia," accepted Christianity, subject gradually the Alemans, Thuringians, Bavarians and Frisians, under Charlemagne (768–814) also the Saxons, and effect the first union of the Germanic tribes. In 843 the great Frank dominion by the treaty of Verdun is divided into three parts, and that is the political beginning of both France and Germany.

Meanwhile important developments of other nature are taking place in the eastern parts of the territory that eventually will be comprised by Germany.

The main region of the early Germanic tribes lay west and southwest of the Saale and Elbe Rivers. To the east and northeast of this territory lay extensive lands, hilly in the south, sloping towards the north and terminating in vast flats. All these parts, up to the Vistula River, more than twice as large as the Germany proper, were represented by Tacitus and other early historians as belonging to "Germania," though the knowledge of them until long after was very hazy, and the concept of the "German" people was far less crystallized than it is to-day. It is impossible to cover this great region with any known German tribes. The prevalent notion,

[5] There is still the province of Burgundy in western France.

[6] The French name for Germans is to this day "les Allemans."

held especially by German writers, is that the region was vacated by Germanic peoples. But, even if all the more eastern Germanic or Scandinavian groups that moved southward from the first century onward could be attributed to it—which it seems they can not—the territory could still nowhere near be filled, even in its more favorable parts for human occupation. Here is a serious unnatural void of which no one has given as yet a plausible explanation.

As history begins to unfold, however, this great expanse is found filled, even if not thickly, by non-Germanic elements. There are the *Aesti*—undoubtedly the old Lithuanians—in what is now Eastern Prussia; and the rest is filled with the large group of *Lugii*, which name is evidently of Slavic derivation (*lug, luh* = field, meadow), and with many tribes of Slavs. These are assumed to have spread over the country from beyond the Vistula after the Germans moved out. This assumption is unsatisfactory. If the Slavs moved in and stayed, then the country could not have been worthless and would not have been abandoned by its older inhabitants. Nor were the Slavs of the time as well armed as the Germans so that they would have been able to drive the latter out, besides which there is no mention anywhere of such a major event, which would have caused as great disturbances, at least, as the Hunnish invasion in 375 of the Goth territories further southeast.

The *Venedi* (Slavs) are first mentioned, in the first century A.D., by Pliny and then by Tacitus, but these notes are scant, not based on original observations and indefinite. Ptolemy, in the latter half of the second century, while still not original and in many respects in error, gives more information. He knew of the Venedi now as a "megiston ethnos," a great population, whom on his map he places along the Baltic and the "kolpos Venedinus" (Venedic Bay), to the east of the Vistula River, and in "Sarmatia," placed in present Poland. By the end of the sixth century they are already generally known of, and found to occupy almost the whole great region from what are now southeastern Denmark and Pomerania, to the right of the Elbe and Saale Rivers, and to the southern boundaries of Bohemia and Moravia. "By the end of the sixth century the whole basin of the Elbe, except the Saxon territory near the mouth, had probably become Slavonic" (Latham; Encycl. Britan., XI. ed.; et al.).

The term *Slavs*, or Sclaveni, like that of "Germans," is not an original generic name of the Slav people, as was not that of the Wends or Winds or Venedi. The latter terms were applied at first to only the Baltic Slavs, but came eventually to be used for all their neighbor Slavs by the Germans. Their origin is unknown. The name "Slavs" is believed by many to have been derived from "slovo," the word, but proceeds more probably from the extolling affix "slav" (from slava, glory), used in many of the personal Slav names in early times and occasionally even now. It occurs in both Procopius and Jordanes, the principal historians of the sixth century. Both the names, Vends and Slavs, extended to many tribes related by blood and language, but, as is true of the early Germans, not united and practically independent of each other. Linguistically the stock belonged to the Aryan family of languages, being related most closely to the Lettish and next to the German. Physically they were, according to reliable indications, predominantly light-haired, medium-statured, sturdy people, originally probably mostly of oblong head, differing but little from the central Germans. They were essentially agricultural people, lived in numerous characteristic villages, but had also some cities and famed sanctuaries. Their cradle was the great

region north of the Carpathians, from the watershed of the Vistula to the Dnieper River. They were "pagans," with a religion related in general to the Greek, and recognized one chief deity. They were not militarily as developed as the Germans or Romans, but were sturdy fighters. In their ever recurring struggles with the Germans in the west and the eastern Roman empire in the east they both took and lost many prisoners—men, women and children—which in time served to admix both of the contending sides.

German historical literature, even though largely biased, and also the Danish, are full of testimonies about the Slavs of the eastern portion of Germany and their gradual absorption. This absorption of the ununited Slav populations continued systematically and often forcibly from the time of Charlemagne in the latter part of the eighth to beyond the fifteenth century, without to this day being completed or ended. The principal means were domination, colonization and Christianization. The process, as now, was mainly "by the sword and the fire"—"ferro et igni vastavit" (old reports). And it was not uniformly successful. Toward the end of the tenth century "the Slavs fought with such courage and success that during the reigns of the emperors Otto II and Otto III much of the work effected by the Margraves Billung and Gero was undone, and nearly two centuries passed before they were driven back to the position which they had perforce occupied under Otto the Great." (Enc. Br., XI ed.) In 983 a particularly great Slav revolt stopped the Germanization and this could not recommence until the middle of the twelfth century. "By that time were Germanized only the Main and Rednitz Slavs with those of the lands between the Saale and Elbe." (Gr. Brockhaus).[7]

[7] "Um die Mitte des 12 Jahrh. hatte die Unterwerfung der Slawen an Havel, Elbe und Oder begonnen, vor allem durch Albrecht den Bären, der die alte Nordmark zur Mark Brandenburg erweiterte, und durch Heinrich den Löwen; nach dessen Sturz wurden die slawischen Fürsten in Mecklenburg und Pommern selbst reich-unmittelbare Herzöge. . . . Schlesien wurde auf dem Wege der friedlichen Germanizierung allmählich für Deutschland gewonnen." (Brockhaus, IV, 677).

The testimonials of the absorption into the "German" stock of the large mass of western Slavs are a legion and it is not necessary to search for them outside of German sources alone.

In the twelfth century the Danish kings used also the title "kings of Slavs." Pomerania, the large northern province of present Germany, was wholly Slavonian until well after the middle of our era. In the words of Latham ('51, p. xvii), "Adam of Bremen first mentions these Pomeranians, and he mentions them as Slavonians, the Oder being their boundary to the west. On the east they were conterminous with the Prussians. Their name is Slavonic *po*—on and *more*—sea, *i.e.*, coastmen. All their antiquities and traditions are equally so; in other words there is neither evidence, nor shadow of evidence, of their even having dispossessed an older Germanic population. Nor are they wholly extinct at the present moment." And there are almost endless accounts of and references to the Slavs of the other parts of present east Germany. There are in the German language numerous names relating to agriculture and various old industries that were taken from the Slav. The famed association of trading cities "Hanza" is attested to have been based on Slav trading establishments. A great number of the names of cities, villages, rivers, places, all over the former territory of the Germanized Slavs, are Slav names or corruptions, which would surely have disappeared had their Slav population been driven out or annihilated. The very name of the chief deity of the northern pagan Germans, Wotan, Wo-

dan, Woden or Odin—may possibly be of Slavic derivation.

Perhaps the most interesting survival of the Slav times in eastern Germany is the name of Berlin, the capital. This name is a corruption of Barliň, an old Slav fishing settlement on the right bank of the Sprewa River. Opposite this, on the left bank, was the Slav town or village of Kolin. The first settlement of Germans is introduced here about 1144, under Albrecht the Bear, who thus began the Germanization of the place. The two settlements on the river were united in 1307; between 1373 and 1415, they with the district belonged to the Czech crown; in the Thirty-Years War the inhabitants were reduced to 6,000; in 1442 Friedrich II built here a strong castle, and from that time on the now rapidly growing place was "Berlin," first the provincial and finally the empire capital.[8]

Rostock is the old Slav Rostok (spread of the river); Lübeck is a twelfth century corruption of Liubice, a local Slav village; Breslau up to 1241 was Vratislav, a seat of a Polish dukedom of the same name, and from 1335 to 1742 belonged to the Czech crown; Leipzig was the old Serb town of Lipsko, mentioned also as Lipzk, Lipzek, Lipzik, from which since the fifteenth century the "German" Leypzik to present Leipzig was derived. And the list can be much extended. Many of the family names of the eastern larger half of present Germany also are Slavic or easily recognizable corruptions.

Besides the Slavs, the Germans, since the twelfth century, have incorporated with themselves and Germanized also other eastern populations. The chief of these were the Birussians or "Prussians," a branch of the old Lithuanians, living in parts of what is now Eastern Prussia. The forcible subjection of the tribe, once more "by the sword and fire" and under the guise of Christianization, was carried out between 1232 and 1283 by the Order of the German Knights. The Birussians were largely annihilated, German colonists were settled in the country and the German Reich was enriched by a new province. Ironically the names of "Prussia" and "Prussians" stayed, spread to "western Prussia," and finally became those of the large dominant and most militant parts of the German realm and people.

Slowly advancing has also been and is now the Germanization and absorption of the Slavs of western Poland. A forcible process, such as affected the Birusi, was tried by the same Order of the German Knights, but the Poles proved too strong and the effort came to an end in 1410 at the battle of Grünwald, from the effects of which the Order never recovered. However, the three divisions of Poland, 1772, 1793 and 1795, between Prussia, Austria and Russia, opened once more the door to Germanization, especially of Poznaň (Posen) and the Baltic part of the country, and this proceeded until the First World War, at the end of which the former western boundary of Poland was restored. From 1772 to 1918, however, many of the western Poles were assimilated into the German mass, introducing thus further Slav admixture.

Since the early parts of the second millennium of the Christian era and up to the 1914–1918 war, slow but constant and strenuous efforts were carried on also at Germanization of the desirable Bohemia and Moravia. German artisans, traders and colonists occupied gradually parts of both lands, were favored in every way at the expense of the Slav population, and every agency, including again the "sword and fire," were used; but with little final success. The "sword," domination, systematic forced colonization, are once more in full action, and the fate of Lidice has shown

[8] G. Langenscheidt, Naturgeschichte der Berliner; Ottos (Czech) Encycl.; etc.

that "fire" is only awaiting its turn. Still worse action is taking place in Poland and in the occupied Baltic and Russian provinces. The German blood needs more Slav "fertilizer," as cynically acknowledged on occasions.

Southern Admixture

Long before the Germans impinged on the western Slavs—or long at least before this is recorded—they came into contact with the Gallic or Keltic peoples in the south. These, while equally a part of the great White Stem, belonged to the "Alpine" or mid-European race. They were of darker hair and eye pigmentation, robust and well built, in general of medium stature. They originally occupied and were evidently indigenous to the great Alpine region from the middle Danube westward, covering the old Rhaetia (Austria-Tirol), Bavaria, with present Württemburg, Baden, Palatinate, Rhineland and Alsace-Lorraine, Helvetia (Switzerland), Gaul (France and Belgium) and also parts of Britain with Ireland. Just when the Germans came into contact with these is not known—it must have been well before the advent of the Romans, for by that time all serious violence had ceased and the people of what became the southern German states already spoke German. There are known, however, the later influxes of the Alemani, Marcomani and Suabi, and later those of the Franks, Burgundians and other tribes, and as far as these affected lands now united into "Germany" they represented so many agencies of admixture. The results of all this was a greater or lesser fusion of the more northern elements with the Alpines, leaving a mixed population. The amount of this southern miscegenation was probably not incomparable with that of the Slavs in the east, and each may perhaps roughly be estimated at about one third of the resulting "German" body.

Additional Admixtures

In the course of time the original Germanic tribes received additional minor admixture of heterogeneous units. There were the Borussian or Lithuanian accretions in the northeast, some mongoloid blood during the large Asiatic invasions, before these some Mediterranean infusion during the Roman wars, Dutch and Scandinavian elements, and finally, in the course of centuries, some Jewish accession. None of these were of much moment; nevertheless together they added to the admixture of the original more "nordic" Germans.

Most of this miscellaneous mixture took place in the larger cities, and not seldom was invited or favored. Thus we read in the histories of Berlin that from the fifteenth century on it welcomed many newcomers and refugees, from Switzerland, Italy, France, Bohemia, Holland and other countries. According to Langenscheidt the modern Berlin is regarded as "a German-speaking neutrum," and holds approximately 39 per cent. of French, Belgian and Italian elements, 37 per cent. of German and 24 per cent. of Slav.

Physical Evidence

Strangely, though the Germans before the first World War stood in the foreranks of science, including anthropology, the people of Germany have never been thoroughly studied and so the somatic picture of them is still incomplete. This is hard to explain, unless it be attributed to a disinclination to show both to themselves and to others how really far from homogeneous is the German nation.

There were nevertheless more or less limited studies that indicated the conditions. At the head of these stands the survey in the seventies of the last century, by the teachers of public schools, of nearly seven million of the school children of the country. This survey

was carried out under the auspices of the Berlin Anthropological Society, and the results were reported in 1876,[9] and especially in 1885, by Rudolf Virchow.[10]

The total number of children examined was 6,758,827 from all parts of the empire, of which 75,377 (1.1 per cent.) were Jewish. They ranged from six years to high-school age, a very large proportion being below 14. Noted, under instructions from the society, were only the color of the hair, eyes and skin. Though the pigmentation of the hair has not yet reached its final stage—the hair in general darkens progressively until well in the adult stage—the results showed that there was far from any general blondness or any uniformity between the different parts of Germany. The main results for the 6,758,827 children examined were as follows:

Type	*Per cent.*	*Hair*[11]	*Per cent.*
Blond	31.80	Blond	68.02
Brunette	14.05	Brown	29.42
Mixed	54.15	Black	1.98
		Red	0.25
Eyes		*Skin*	
Blue	39.55	Light	91.50
Brown	27.21	Brownish	8.45
Grey	33.18		

Jewish children showed throughout darker. The territorial distribution of types were:

	Blonde	*Brunette*
Northern	33.56 per cent.	11.17 per cent.
Central	25.29 " "	14.74 " "
Southern	18.44 " "	25.21 " "

[9] Beiträge zur physischen Anthropologie der Deutschen. *Abh. k. Akad. Wiss.*, Berlin, (1876) 1877, 11 *et seq.* And *Verhandl. Berl. Ges. Anthrop.* etc., 1876, 16–18.

[10] Gesammtbericht über die von der deutschen anthropologischen Gesellschaft veranlassten Erhebungen über die Farbe der Haut, der Haare und der Augen der Schulkinder in Deutschland. *Arch Anthrop.*, XVI, 1885–6, 275–475.

[11] As light hair generally darkens more or less with age, the proportion of lights in adults would be considerably smaller and that of the darks larger.

The blonde type ranged from 9 per cent. in a locality in south Germany to 56 per cent. in part of Oldenburg. In the left Rhine zone (Alsace, Lorraine, Palatinate) it was but 16 to 18 per cent. In parts of Oberpfalz and much of Bavaria the blonds were reduced to 9–14 per cent. In individual districts the brunette type ranged from four per cent. in a part of Oldenburg to 91 per cent. in a part of southern Germany. The "mixed forms" were recorded as 40 to 69 per cent. of those examined in different localities.

The mixed nature of the German people is fairly acknowledged by the author (Virchow). Thus, on p. 323, he says: "The results convey the view of a marked *southern zone of mixture, which extends through Germany in south-north direction"*; p. 324: "There is a multitude of mixed forms"; and, p. 326: "It is surely very remarkable that *exactly one-third of all German school-children have grey eyes.*"

The whole showing of this highly valuable survey demonstrated clearly, though still incompletely, the mixed nature of the German population. Incompletely, because many of the Slavs were as light-haired and all as light-skinned as the Germans, so that their admixture could not show in a study of this nature.

The German Skull

There are many contributions in German to the knowledge of the German-territory skulls, but a definite collective and unbiased work on the subject is still wanting. Some of the main studies are noted below,[12] and they give references

[12] Crania Germaniae. Freiburg, 1865 (various workers); J. Ranke, 1880—Die Schädel der altbayrischen Landbevölkerung. Beitr. Anthrop. Urgeschichte Bayerns, III, 108–205; J. Kollman, 1881—Beiträge zu einer Kraniologie der europäischen Völker. Arch. Anthrop., XIII, 179–232; Katalog der anthropologischen Sammlungen Deutschlands. Publ. by various workers in the 80's and 90's of last century; A. Schlitz, 1910—Die vorgeschichtlichen Schädeltypen der

CEPHALIC INDICES IN THE VARIOUS PROVINCES OF GERMANY

to others. Data on the subject in English are scarce and scattered.[13]

The evidence may be summarized briefly. As with pigmentation, the German skulls vary greatly according to locality. The cranial ("cephalic") index ranges from low dolicho- to the highest brachycrany. There are long and short, high and low skulls, small and large. In general the southern German lands, Bavaria, Baden, Alsace, with their neighboring regions, show a predominance of the short and broad Alpine type of the skull, while in the northwestern parts the skull is more commonly oblong, approaching a similar type in the Scandinavian countries. Even in the old row-burials, however, which are regarded as particularly characteristic of the protohistoric Germans, the skull type already differed, as did also stature and other features.[14]

Present Head Form

Among the living Germans, oblong heads, and hence skulls, which are claimed as the true German, are in general much less frequent than the broad and short or brachycephalic. This is a matter of common observation, but also of some independent scientific researches.

During the first World War anthro-

deutschen Länder. Arch. Anthrop., IX, 202–251; E. Hug, 1940—Die Schädel der frühmittelalterlichen Gräber aus dem solothurnischen Aaregebiet in ihrer Stellung zur Reihengräberbevölkerung Mitteleuropas. Z. Morphol. & Anthrop., XXXVIII, H.E., 359–528; w. Bibliog.

[13] For a spirited chapter on the whole subject of germanism and physical anthropology see W. Z. Ripley's "The Races of Europe," N. Y., 1899, 213 *et. seq.*

[14] An especially explicit note on the subject is found in Walther Kruse's large work on "Die Deutschen und ihre Nachbarvölker," 8vo, Leipzig, 1929, p. 220: "Wie wir gegenüber Schliz ganz bestimmt versichern können, zeigen auch die altslawischen Schädel *in allen eben besprochenen Punkten keine characteristischen Vershiedenheiten von den germanischen.*" (Ital. in orig.).

pological measurements were taken by Parsons and Le Gros Clarke on respectively 925 and 840, or in all, 1,765 prisoners of war, coming from all parts of Germany.[15] The average cephalic index of the group was 82.5, or plainly brachycephalic; and it ranged, according to the provinces, from 80.4 in Westphalia and close to 81.0 in the western regions, to 84.1 in Bavaria and 84.6 in Silesia.

Even in the most blond Oldenburg it was 80.6, or low brachycephalic. The results are shown in the accompanying map of Dr. Parsons. In his words, "The most striking lesson is that nowhere in Germany of today could I find material with a cephalic index below 80." An index from 75 to 80 denotes, as is well known, mesocephaly, which prevails both in England and in the old American stock; and only below 75 commences dolichocephaly. It is true that in the skulls the German indices would be about 1.5 points lower, but this would make only little difference. The final conclusions of Parsons is that "the prisoners at our disposal give us no reason for thinking that there is any part of modern Germany in which the Alpine or Slav characteristics have not dominated the Teutonic or Nordic."

Parsons and Clarke have also observed the pigmentation of the hair and eyes in 3,350 of the German prisoners, and the results show in the various provinces of from 10 (Hanover, Mecklenburg) to 37 (Alsace) per cent. of "pure brunettes,"[16] which does not differ very materially from the results obtained by the previously dealt with survey of German school children.

Parsons records also the measurements of stature of 1,545 subjects. The means ranged from 5′ 6.1″ in Württemburg and Bavaria to 5′ 8.1″ in Mecklenburg—once more substantial differences.

[15] F. G. Parsons, Anthropological Observations on German Prisoners of War. J. Anthrop. Inst., Lond., 1919, XLIX, 20–35.

[16] Those in whom dark to black hair was accompanied by brown eyes.

German Immigrants

The second and independent series of measurements on adult Germans were taken under my direction by Dr. Mary T. Mernin, on Ellis Island, the New York gate for immigration. They extended to 100 normal but otherwise unselected males 24–58 years of age, and the measurements were taken with especial care so that they might safely be used for scientific comparisons. The men came from various parts of Germany and close to 90 per cent. bore strictly German names. The average stature of these men was 170.4 cm (5 ft. 7 in.), but ranged from 156.1 to 186.2 cm. The mean cephalic index of the 100 was *83.15*, with the range from 70.6 to 93.3, or from dolicho- to hyperbrachycephaly.

Some exceedingly interesting comparisons are now possible with an equal-sized series of incoming Frenchmen, measurements on which were taken at Ellis Island by the same person as well as methods and during the same period. Here too the subjects came from various parts of France and come probably close to representing the general average status of the population. It will be of advantage to contrast in this case all the determinations and to compare the same also with those obtained on Old Americans.[17]

The statural and also the absolute weight in the Germans are slightly higher than they are in the French, both being lower than the Americans; but proportionately to stature the French are slightly superior in weight to the Germans.

In the arm-spread both the French and the Germans show some excess over the Old Americans—their arms are relatively somewhat longer.

In the height sitting the Germans show slightly the highest, with the French close next, and the Americans close last.

All through these several determina-

[17] A. Hrdlička, "The Old Americans." Baltimore, 1925.

TABLE 1

MEASUREMENTS OF GERMAN, FRENCH AND AMERICAN ADULTS
Average Weight and Stature in Metric Units

Group	Subjects	Ave. age yr.	Stature cm.	Weight kg.	Weight : grams per cm. stat.	Arm-spread per cent. of stature	Height sitting per cent. stature
Germans	100	30.5 (24–58)	170.4	67.5	87.3	104.3	53.3
French	100	30.0 (24–58)	168.8	67.0	87.6	104.9	53.1
Old Americans[18]	250	42.5 (24–60)	174.5	68.2	86.2	102.7	52.9

tions the Germans and French are closer together than either of them is to the Old Americans.

The head of the Germans is the broadest and shortest giving the highest cephalic index (Table 2). The French of our series give actually appreciably lower index than the Germans.

In the height of the vault the Germans and the French are again considerably alike with the Americans above both of them.

The size of the head is absolutely greatest in the Old Americans, with the Germans and French closely alike. Relative to stature the French head shows slightly the best, the German close second, the American last (due to the elevated stature).

The facial dimensions are practically the same in the Germans and the French, but the face is narrower in the Old Americans. All this is reflected in the indices (Table 3).

TABLE 2

HEAD

Group	Length cm.	Breadth cm.	Height[19] cm.	Mean head diam. cm.	Mean head diam. *vs.* stature	Cephalic index	Mean height index
Germans	19.1	15.9	13.6	16.19	95.0	83.1	77.5
French	19.2	15.7	13.5	16.14	95.6	81.7	77.2
Old Americans	19.8	15.5	13.9	16.40	94.0	78.3	79.0

The forehead is slightly the lowest in the French, due to slightly lower descent of the hair. In breadth it is a trace narrower in the Americans, in correlation with the lesser breadth of the vault.

The breadth of the lower jaw at its angles is the same in the Germans and the Americans, slightly greater in the French.

Once more there are astonishingly close relations between the Germans and the French.

TABLE 3

FACE

Group	Total height—hair line	Height to nasion	Greatest breadth	Facial index total	Facial index, lower	Height of forehead[20]	Smallest breadth of forehead	Lower jaw breadth at angle
Germans	18.3	11.8	14.2	77.5	83.1	6.57	10.8	10.6
French	18.3	11.9	14.2	77.3	83.8	6.34	10.7	10.8
Old Americans	18.5	11.9	13.9	75.1	86.1	6.58	10.6	10.6

[18] Laboratory series.

[19] See writer's "Anthropometry," Philadelphia, 1920, '39.

[20] Where unaffected by loss of hair.

TABLE 4

Group	Nose			Left Ear		
	Height	Breadth	Index	Height	Breadth	Index
Germans ..	5.45	3.56	65.3	6.46	3.72	57.6
French ...	5.43	3.62	66.6	6.46	3.85	59.6
Old Americans	5.35	3.61	67.5	6.69	3.79	56.7

The nose and also the ear show close similarities in the three groups. The slightly relatively broader nose in the Americans is connected with the greater average age of the Americans.

The somewhat marked excess in ear length in the American group is doubtless due also to the higher average age. The French ear is slightly the broadest, but its height is identical with that of the Germans.

TABLE 5

Chest (at height of nipples)

Group	Breadth	Depth	Index
Germans	29.7	21.4	72.2
French	30.4	22.3	73.2
Old Americans ...	29.8	21.7	72.9

The chest shows slightly the best in the French, particularly in relation to stature, but the differences are small (Table 5). The chest index too is much alike in the three groups.

TABLE 6

Group	Left Hand			Left Foot		
	Length	Breadth	Index	Length	Breadth	Index
Germans ..	19.3	9.3	48.5	26.6	10.2	38.3
French ...	19.35	9.4	48.4	26.4	10.0	37.8
Old Americans	19.3	9.2	47.6	26.1	9.5	36.3

The hand and foot are almost identical in the Germans and the French, somewhat narrower in the Americans (Table 6).

TABLE 7

Strength in Hands

Group	Pressure (in kg.)[21]		Traction (bimanual)
	Right hand	Left hand	
Germans	39.7	37.3	20.1
French	39.1	37.2	21.4
Old Americans ..	41.8	36.1	22.3

[21] With Mathieu and Colin dynamometer.

In the strength of the hands, both pressure and traction, the Germans and French are again very much alike, and both are close to the Americans, in whom however the disproportion between the right and the left hand is somewhat greater (Table 7).

In this connection it may be said that while the Old Americans stand somewhat apart, the Germans show so many and so close similarities with the French that no closer relations could be expected between any two like groups of Germans themselves. This is, of course, only in the averages which cover a multitude of variance.

But such averages are of very much value in general comparisons. They show plainly in this case how unfounded are all efforts at any segregation of the German "race."

Conclusions

There is a German nation, a large linguistic and political unit.

This nation originated in what are now northwestern and western Germany north of the Rhine, from the prehistoric occupants of these regions.

There are indications that the main old stock of these parts was related to the principal stock which in the early neolithic times peopled the Scandinavian countries, but from old showed some heterogeneity.

From prehistoric times to the present day the German people, always strong in numbers as well as in armaments, partly peaceably but largely by force,

have been absorbing their neighbors, the Kelts in the south, the Slavs and in smaller measure the Lithuanians in the east; and the progeny of these accretions admixed more or less the former parts of the nation.

The additions to the old German stock were collectively so numerous that in general they greatly modified the same in pigmentation, head form and general physique.

The Germans to-day are a major complex of Germanic-Keltic-Slav composition, and different basically neither in language nor any special physical or even inborn mental characteristic from other white people. They have become what they are to-day, aside from education, through tradition, habits and especially indoctrination.

Racial pride, while not inborn, is, wherever conditions permit, a universal part of both our idealism and egoism, and within bounds is a potential agency for much that is beneficial. But if not held within wholesome limits or if fanned by the demagogue for his own designs, it may readily pass into conceit, arrogance and strife.

There has never been nor is there now any nation of any accomplishments that did not regard itself as superior, in the line of those accomplishments at least, to others. Where the accomplishments alone do not suffice it will draw upon fabled descent, with overexalted ancestors. And woe to realities and even good common sense where there is some justification for the self-esteem. In that case facts of any kind that disturb must give way. They are colored differently, or roughly denied and passed over. "Racism" is a psychological phenomenon, but may be made into a powerful agency for temporary unity of a people and its following of self-imposed leaders.

HIGHER EDUCATION IN CHINA

By Dr. ZING YANG KUO

DIRECTOR, INSTITUTE OF PHYSIOLOGY AND PSYCHOLOGY, CHUNGKING, CHINA

In 1912, when the Chinese Republic was established, there were only four institutions of higher learning with a total number of students below five hundred (461) and with an annual expenditure of $755,730 Chinese currency, according to a recent report by the Ministry of Education of the Chinese National Government. By the time when the war began in 1937, the total number of universities and colleges in China had increased to 108, with a total enrolment of 31,188 students. The annual budget for higher education for the year 1937 was $35,574,896 Chinese currency. The rapid progress and expansion of higher education in China during the twenty-five years previous to the war are clearly indicated by these figures. But the improvement in the quality of teaching in universities and colleges is even greater than the increase in the number of schools and students.

During the last four years, the Japanese army and air forces have been deliberately and systematically destroying Chinese educational and cultural institutions. Those located in the areas occupied by the Japanese troops have been plundered or forced to discontinue their work, while those situated behind the Chinese lines have been systematically sought out and bombed from the air. Of the 108 universities and colleges and technical schools at the outbreak of hostilities, fourteen were totally destroyed, while eighteen were damaged to such an extent that it has been impossible to

operate them. Seventy-three other institutions which were removed to the interior can not utilize the equipment they originally had and are operating on very scanty resources. The total losses of property sustained by the Chinese universities and colleges as a result of the war have been estimated at $65,200,000 Chinese currency. The total losses of books are well over ten million volumes.

In spite of the great losses and destruction, the Chinese universities and colleges are still operating on a more or less regular schedule. At present there are 104 universities, colleges and technical schools operating on a regular schedule. Most of these schools have been removed to the interior. Of these 104 institutions of higher learning, 13 are mission colleges, which are operated by missionaries and supported partly by the churches in the U. S. and partly by tuition fees and subsidies from the Ministry of Education of the Chinese Government. Of the some 50,000 students now studying in Chinese universities and colleges, about 7,000 are enrolled in the mission colleges.

The war has not only not diminished the number of students, but has increased it. As noted before, the total number of students at the beginning of the war was 31,188. It was increased to 36,180 in 1938 and to 44,442 in 1939. At present, it is well over 50,000. A great number of these students have come from the areas occupied by the Japanese troops. Many of them had traveled mostly on foot more than one thousand miles to receive their college education in Free China.

While Chinese universities and colleges are still able to maintain their work in spite of the extreme physical hardships which teachers and students have been enduring during the last four years, their suffering from what may be described as "intellectual starvation" is the most unbearable. In a great many cases, both teachers and students are working without library or laboratory facilities. Teachers would lecture from memory or use old textbooks. Students generally work with bare hands, taking down lecture notes with scanty opportunity for collateral reading in the library or for experiments in the laboratory. A great many teachers of science have not seen a single copy of scientific periodicals for more than three years. Under such conditions, it is almost impossible in a great many cases to carry out scientific research except in a very primitive manner. Consequently, there has been a decided downward tendency of the intellectual level among the Chinese colleges and universities despite the fact that the number of students has steadily increased and that class exercises have been regularly maintained.

While China is still at war against an aggressor nation, her educational leaders have already begun to plan for the rebuilding of her culture and education. The work of educational and cultural reconstruction will be started as soon as the war is over, or even sooner, if sufficient assistance and cooperation from the United States can be secured. In fact, while China is fighting for her national existence, she is at the same time remaking the nation. Education occupies a very important part in her program of national reconstruction.

In order to appreciate the importance of China's new program for reconstruction of higher education, the following existing conditions in China upon which the new program is based should be briefly stated:

The war has offered China an excellent opportunity for a long range planning for her national reconstruction. In industry and agriculture, China has already undergone tremendous changes since the outbreak of the war. The time seems to have arrived when China should start her national planning for economic

reconstruction so as to avoid the evils of capitalism and Nazism and the mistakes of Communism. In such a national planning, education—especially higher education—should be included as a most vital part of the new national structure. In planning a new program for her higher education, therefore, great stress should be laid on the training of scientific and technical personnel for national economic reconstruction so that when the economic reconstruction begins, there will be an adequate supply of trained men for various tasks. However, other aspects of cultural studies such as arts, philosophy, literature and humanities, etc., will not be neglected.

At present, there is already a great shortage of trained personnel in various fields, especially in science and technology. When the war is over and reconstruction in industry and agriculture is begun, the shortage of personnel will be very much more acute unless a well-planned program for training men and women for the tasks of reconstruction is worked out well in advance.

At present, most of the university professors in China and most of those who hold important positions in government and in industry were educated in foreign countries, particularly in the United States. Due to the lack of library and laboratory facilities and other resources and to the insufficient number of first grade professors in China, the training of scientific and technical personnel for cultural and economic reconstruction in China will depend, more than ever before, upon sending students to study in the United States and upon inviting American scholars to teach in Chinese universities. Unfortunately, since the outbreak of the war, the number of Chinese students studying in this country has decreased considerably. Arrangements must soon be made so that greater numbers of Chinese students can be sent to this country for scientific and technical training if the program for the reconstruction of China is to be carried out in due time.

During the last thirty or forty years, the Chinese Government had adopted a laissez-faire policy with regard to Chinese students studying abroad, with the result that a great many students did not acquire their training according to the need of the nation and were unaware of those specific and unique problems with which they would be confronted when they returned to China. Consequently, such students often found themselves ill-prepared and unequal to their tasks when they were required to deal with such problems.

The New Program for Reconstruction of Higher Education

Based upon the above facts and conditions, a new program for reconstruction of higher education in China has been evolved. It may be briefly outlined as follows:

1. A long range national program for the development of higher education during the next fifteen or twenty years is to be laid out.

2. This program will be based upon and coordinated with economic reconstruction of the nation.

3. A nation-wide survey is to be made to ascertain the number and kinds of scientific, technical and professional personnel which will be needed during the next fifteen or twenty years for industry, government services and for teaching in universities and colleges. Based upon this survey, the number of graduate students to be trained each year in China and in the United States will be determined.

4. Every effort will be made to discourage establishment of new universities or colleges and to close down those which fail to comply with required academic standards. Unnecessary duplica-

tions in instruction and research are also to be discouraged and reduced to a minimum.

5. Although at present there are still 104 universities and colleges in operation, in view of the lack of adequate teaching staff and resources, we shall not attempt to re-equip all of them and bring them all up-to-date. On the contrary, we shall select only four or five out of these 104 institutions and concentrate our efforts on rebuilding them, bringing them up to modern standards and making them as centers for training graduate students in China. Material and financial aid from the United States will be used mostly for the rebuilding of these four or five selected institutions. It is hoped that arrangements can be made to bring visiting professors from American universities to teach in these selected centers in China. These centers, however, will not be able to turn out sufficient numbers of trained men to meet the needs of the nation. We must, therefore, look forward to sending a great number of students to be trained in the United States.

6. With reference to sending students to study in the United States, the following principles will be adopted:

(a) The laissez-faire policy will be abandoned.

(b) No students will be permitted to come to study in the United States unless they have fulfilled the requirements as to academic qualifications, practical experiences, and specific projects of study. This will be applied to all the students supported either by public or private funds.

(c) Only graduate students with practical experience in teaching, industry or government service will be sent to study in the United States. They should come with definite aims and projects and should know what they are expected to do when they return to China. They may not be required to follow the courses of study as prescribed for American students.

(d) A well qualified person is to be sent to the United States to act as the councilor for Chinese students studying in America.

This is the gist of the new program for reconstruction of higher education in China, upon the success of which not only the rebirth of China's culture, but also her economic reconstruction depend. The task will be tremendous. But we shall try to carry it out with firm resolution. However, in view of her exhausted conditions due to the war, China will not be able to accomplish this task without American assistance and cooperation.

DAVID DALE OWEN, MAN OF SCIENCE

By Dr. WALTER B. HENDRICKSON

DEPARTMENT OF HISTORY, MACMURRAY COLLEGE

DAVID DALE OWEN, one of the leading geologists of the United States a hundred years ago, was one of the second generation of scientists who made New Harmony, Indiana, their home. Following the trail blazed by William Maclure, Thomas Say, Gerard Troost, and Charles Alexander Lesueur, the son of Robert Owen carried on scientific research in geology, chemistry, and paleontology.[1] At first he worked almost alone, but as he gained experience and enhanced his reputation, he gathered around him a circle of scientists who were leaders in their fields in the 1840's and 1850's. In the little town on the Wabash River, Owen built and maintained a large laboratory and museum which became the center of his operations as he worked on geological surveys for the United States government and for the states of Kentucky, Arkansas, and Indiana.[2]

What manner of man was this hard working, inquiring geologist? In the report of his most extensive and elaborate survey, that of Wisconsin, Iowa and Minnesota there is a portrait of the scientist.[3] It pictures an alert, rather handsome man with a high forehead, straight nose, sensitive mouth and strong chin. Owen's deep-set eyes were blue and his wavy hair brown. He was moderately tall, and though slight of frame, possessed a wiry strength and great stamina. Always immaculately dressed, he affected clothing in shades of gray. He was graceful in his movements, a skilled ice skater and an elegant ballroom dancer. A cultured gentleman, he was schooled in the social graces, and was reserved and quiet in public.[4]

David Dale Owen married Caroline Neef, a daughter of Joseph Neef, a former New Harmony school teacher, in 1837. When they returned from their wedding trip they moved into the "Owen Mansion" with Dale's brother Robert and the latter's wife. This arrangement continued for some years, but when the brothers' children became older, other plans were made. Dale sold his interest in the family home to Robert and contemplated the purchase of the house in which his sister, Jane Owen Fauntleroy, lived.[5] The sale was never consummated, but Dale and his family moved in with Jane and remained until Owen acquired a large dwelling near his laboratory.

This house, first built as a residence by Father George Rapp, leader of the religious group that originally founded the town of New Harmony, was later occupied by William Maclure and then passed to his brother and sister, Alexander and Anna Maclure, upon the death of their brother.[6] Erected as a two storied house, it had been converted into a one floor "cottage" with very high ceilings. It was a beautiful place with

[1] C. A. Browne, "Some Relations of the New Harmony Movement to the History of Science in America," in *The Scientific Monthly*, XLII (1936), 488–493.

[2] See Walter B. Hendrickson, David Dale Owen, Pioneer Geologist of the Middle West, Ph.D. Thesis (ms.) Harvard College Library.

[3] D. D. Owen, *Report of a Geological Survey of Wisconsin, Iowa, and Minnesota . . .* (Philadelphia, 1852), 206.

[4] Caroline D. Snedeker, *The Town of the Fearless* (Garden City, 1931), 295, 302. Mrs. Snedeker is David Dale Owen's granddaughter.

[5] This house, known today as "The Old Fauntleroy Home," has been taken over by the New Harmony Memorial Commission, and is open to the public.

[6] This house, known today as the Rapp-Maclure-Owen House, is still occupied and is open to the public.

D. D. Owen.

spacious rooms and handsome fireplaces. There was a long and wide center hall with living and bedrooms on each side and a huge dining room at the end. Owen filled the house with books and pictures, some of the latter from his own brush. The hall was a museum with shelves along each side for the display of geological specimens. One of the most prized was a complete Ichthyosaurus from Germany which was an object of wonder to the Owen children.

The management of the household was left almost entirely to Mrs. Owen because her husband was either away from home engaged in field work, or if in New Harmony he was continually occupied in his laboratory. Caro, as Owen called his wife, managed the large house efficiently. In the garden plot and greenhouse nearby, vegetables and fruit were grown for the table. An ice house and smoke house were also part of the establishment. But Dale did take an interest in his home and occasionally bought things for it after consultation with his wife. At one time, though, he must have embarrassed her by sending home a whole bushel of hominy without asking if it was needed.[7]

Caro was somewhat in awe of her distinguished husband and had the mid-Victorian attitude that since he was the master of the house everything should be done to make him happy and comfortable. She admonished the children to be on their best behavior when he was present, and told them that their father was not to be disturbed nor inconvenienced under any circumstances. Yet Caro and Dale were very close to one another, each being completely in the other's confidence. Dale wrote Caro the details of his surveys and discussed matters of finance with her. His letters were cheerful and intimate and he exercised his great powers of description to make his life in the field real and vivid to her.

Four children were born to Caro and Dale: Alfred in 1841; Anna, 1843, William, 1847; and Nina, 1849. Owen loved his children and was always gentle and patient with them. Nina, the youngest, was permitted to go into the museum and laboratory and play about among the specimens and apparatus. Realizing the benefits he had derived from his own European education, Owen sent Alfred abroad in care of his sister, Jane, to attend school in Germany.

This quiet man had few interests outside of his home and his scientific work. He took no part in politics and his party affiliations are unknown. It may be presumed that he, like his brother, Robert Dale Owen, was a Democrat. Dale's appointments in the federal service were obtained in part through his brother's political connections. In fact, one of the main points made by Robert's opponent in the Congressional election of 1847 was that he "had got every brother and brother-in-law he had into *lucrative office.*"[8] One other indication that Owen adhered to the party of Jefferson and Jackson was that he permitted enthusiastic supporters of Stephen A. Douglas to erect a campaign banner in front of his house in 1859.

The Hoosier geologist, however, held definite economic views to which he gave expression in many of his geological reports. He believed that the government should make resources available to the citizens; beyond this government had no further responsibilities. The best interests of all the people would be served by the utilization of the potential wealth in the ground, even though ore deposits were turned over to private individuals

[7] These and other details have been gathered from Owen's letters now in the possession of Mrs. Caroline D. Snedeker, and have been cited with her permission.

[8] R. D. Owen to Richard Owen, New Harmony, August 21, 1847, Richard Owen Papers. (Italics in the original.) These papers are in the possession of Mrs. Aline O. Neal, New Harmony, Indiana.

for exploitation. Owen was disturbed because Americans were not making full use of their mineral resources. He noted that the United States annually imported large quantities of lead although already possessed of huge reserves of ore in its own rocks. This practice, Owen said, prevented the nation from having a favorable balance of trade. Full utilization of lead and iron resources would stop the drain on the stock of gold bullion in the United States caused by the large importations.[9]

Although Owen in his later years wrote and spoke on nothing but scientific subjects, early in his career he made two public addresses in which he revealed some of his social and economic ideas. In 1844 he addressed the New Harmony Temperance Society. In his lecture the geologist emphasized the harmful physiological effects of alcohol. He said that if habitual drinkers were made aware of the damage that ardent spirits did to the body's organs they would cease their overindulgence. Owen based his cure for intemperance on the theory that "knowledge of the consequences of immorality is one of the strongest motives to morality."[10] The geologist approached the temperance question coldly and logically and advanced a solution drawn entirely from his own early medical studies and scientific training. He said nothing of the social implications of intemperance nor of the difficulties in the way of the regulation of man's personal habits and appetites. Owen failed to plumb the depths of this sociological problem, and merely expressed the theoretical views of the man of science.

Owen again drew upon his technical information in a Fourth of July oration that he delivered in New Harmony in 1845 in which he sought to explain the dangers which threatened the liberties of Americans. Although he admitted that political liberty had brought untold blessings to the people, he pointed out some of the "politico-economic paradoxes" which prevented the fullest realization of complete personal freedom. Particularly did he emphasize the fact that poverty and hunger existed in a land of plenty, that education was not available to the masses, and that, in spite of great mechanical advances, men still had to labor hard and long for small wages.

For the mitigation of these evils Owen had no concrete plan. He only said, "Necessity will come to our aid, . . . experience will guide us in the path: hope will cheer us on our way, confidence will ensure success." The "one bright star" was the law of progression which had been working throughout human history to bring political liberty to perfection. In earth history, too, the geologist found evidence of the operation of this same law of progress. Geology, "this searching—this penetrating science," he said, has proved that "race after race has passed away and become extinct, to be succeeded again and again by other forms belonging to higher orders in the scale of the animal kingdom." In the study of geology Owen discovered conclusive proof that "there has been, from the earliest periods, a continual accumulation and concentration of nervous and intellectual power—a tendency upwards, a striving after perfection—a law of apparently illimitable progression. . . ." Owen closed his address on a note of optimism and hope, saying, "With such evidence of the law of progress, and knowing the immense resources of science and art, what need, then of despondency? What more animating—more encouraging stimulus to labor in the cause of human perfection?"[11]

[9] D. D. Owen, "Report of a Geological Exploration of Part of Iowa, Wisconsin, and Northern Illinois . . . ," *Executive Document* 26 Cong., 1 Sess., No. 239 (June 30, 1840), 39.

[10] *Indiana Statesman* (New Harmony), April 6, 1844.

[11] *Indiana Statesman*, July 12, 1845.

Certainly such sentiments were worthy of a son of Robert Owen. Cast upon a high moral plane, this speech indicated that at one time in his life David Dale Owen shared the optimism and idealism of his father and brothers. The ideas expressed were not original, except perhaps in the application of a scientific hypothesis to sociological theory. So far as is known, the geologist made no more public statements of his Utopian ideals. In his later life Owen was thoroughly absorbed in the practical details of geological surveying, and had little time to consider subjects which did not come directly within his own range of interest. In the field of science he was a profound and penetrating commentator; outside of it his ideas were trite and derived from the thoughts of other men.

In his chosen field the New Harmony scientist was an indefatigable worker. Not only did he accomplish a stupendous amount of field work, but when at home most of his time was spent in his laboratory. He was there early in the morning, came home for noon and evening meals, and, after a romp with the children, or a stroll for exercise, he returned to his office to labor far into the night.

Owen's headquarters buzzed with activity throughout the winter and spring when he was engaged on a survey. Many people of the town found employment there in outfitting the various expeditions. Wagons and carriages were overhauled, tents mended, general camp impedimenta renovated, and boxes made for specimens and cloth sacks made for soil samples.

For use in the field Owen designed a special wagon. It was a small, sturdy vehicle fitted with lockers for carrying instruments and supplies, and having a prairie schooner-like top. The geologist and his assistants often used a carriage for their own transportation while the sub-agents and laborers rode in the wagons. Owen took pride in having smart well-painted wagons and fine animals to pull them. One of his teams won a second prize for working mules at the Posey County fair.

It was in the 1850's that the renaissance of science in New Harmony under the leadership of David Dale Owen reached its height. During these years Owen was engaged on the survey of the states of Wisconsin, Iowa, and Minnesota Territory for the United States government; and he headed the Kentucky Geological Survey, directed the geological reconnaissance of Arkansas, and supervised the second geological survey of Indiana on which his brother, Richard, did the field work. Among the men whom Owen gathered about him were some future leaders of geological work in the Middle West, including Dr. Joseph G. Norwood, first state geologist of Illinois; Dr. A. Litton of the Missouri geological survey; and Dr. Edward T. Cox, a resident of New Harmony and the third state geologist of Indiana. Other leading scientists employed by Owen and who visited the town at intervals were Dr. Leo Lesquereux, the leading paleobotanist of the period, and Dr. William Elderhorst, a distinguished chemist and authority on blowpipe analysis.

In 1858 Richard Owen attempted to capitalize on the presence of these leaders and projected a technical school to be called the Indiana School of Practical Sciences. The laboratories and museum were to be used and Dale and his assistants were to be instructors. Dale was interested in the project because he realized that New Harmony had no commercial future, but felt that it might become an educational center. For some unknown reason the school failed to materialize, and Dale Owen was much too busy with his own work to give attention to the matter. It must have been at least a momentary disappointment to him, though, because he had hoped to enlarge the circle of scientists in New

Harmony, and he had invited Dr. Robert Peter, the chemist employed by Owen on the Kentucky survey, to bring his family and become an instructor in the school.[12]

Although Owen's relations with other men were usually pleasant, he was somewhat impatient with dull wits. Generally soft-spoken, he wielded a caustic pen when aroused by incompetence or failure to understand scientific matters. In 1845 he had appeared in St. Louis to give a series of lectures on chemistry and geology. The audiences were quite small and he barely made his expenses. He wrote to his wife bitterly denouncing the citizens as "ignorant, selfish, moneymaking people with no taste for science." On another occasion he soundly berated an engraver who misinterpreted one of his geological sketches. Yet Owen inspired loyalty and affection in other men. A Dr. Bell of Louisville wrote to a Congressman, " 'Permit me to introduce to your acquaintance Dr. Owen; if you can avoid loving him then I shall consider the age of miracles has come.' "[13] Owen's topographical assistant on the Kentucky survey, Sidney S. Lyon, stoutly defended his chief against attacks by some members of the legislature who wanted to displace him as head of the survey.[14]

The Hoosier geologist was ambitious and he was criticized by jealous rivals. When Owen was seeking the appointment as state geologist of Kentucky, his old assistant in the Northwest, Joseph G. Norwood, who would have liked the place for himself, accused Owen of ruthless acquisition of specimens. Norwood said that Owen personally appropriated all specimens collected on public surveys.[15] Owen, like all confirmed collectors, did use every means to enlarge his museum and his various official positions gave him unexcelled opportunities for adding to it. Norwood's charge, however, was not entirely justified because Owen always obeyed the letter of his instructions and supplied collections whenever they were called for. One can not refrain from believing, though, that the best of the specimens found their way into the New Harmony museum.

David Dale Owen was, as Dr. Peter said, "Unselfish and ever careful to give everyone his due, [and] he always awarded to his various associates . . . their just share of honor and responsibility."[16] Dr. Peter was himself a beneficiary of Owen's generosity. The chemist made so many soil analyses in such a short time that he was accused of falsifying his data. Owen rose to his defense, and in the fourth report of the Kentucky survey gave a careful explanation of the time-saving methods used by Dr. Peter and paid high tribute to his ability as a scientist.

Thus one sees Owen the man and Owen the scientist as one and inseparable, for Owen the man lived only to be Owen the scientist. His relations with his family and with fellow citizens were inextricably bound up with his intense and all-absorbing interest in science. On the other hand he was the same quiet and sympathetic but zealous and particular man in his professional relationships that he was in his home and community. The portrait appears almost naively simple, delineating an honest man with a single purposeful interest.

[12] D. D. Owen to R. Peter, New Harmony, October 30, 1858, Peter Letters. Permission to cite these letters was given to the author by Dr. Alfred Peter, the son of Dr. Robert Peter. They are now the property of Translyvania University.

[13] D. D. Owen to Mrs. D. D. Owen, St. Louis, March 12, 1845, D. D. Owen Papers; D. D. Owen to J. H. McChesney, New Harmony, March 8, 1859, in Indiana State Library; D. D. Owen to Mrs. D. D. Owen, Washington, D. C., February 3, 1853, D. D. Owen Papers.

[14] Sidney S. Lyon to R. Peter, January 2, February 27, March 25, 1858, Peter Letters.

[15] J. G. Norwood to R. Peter, New Harmony, July 3, 1854, Peter Letters.

[16] R. Peter, "Obituary Notice of David Dale Owen," in D. D. Owen, *Fourth Report of the Geological Survey of Kentucky* . . . (Frankfort, 1861), 329.

METEORITES AND THE MOON

By Dr. H. H. NININGER

CURATOR OF METEORITES, COLORADO MUSEUM OF NATURAL HISTORY

THE face of the moon has been the subject of many and varied discussions attempting to offer a satisfactory interpretation of its peculiar features. Nearly all the writers of these articles seem to have assumed that vulcanism on the moon has been established and that the burden of proof that it is not true rests upon those who offer alternative or supplementary hypotheses as explanations of the lunar features. Clearly, any true volcanic activity that may have existed on the moon was so ancient that the resulting topographical features have long since been erased by meteoritic bombardment of its surface. Meteoritic bombardment is an undeniable fact which has been studied on the earth and is known as a cosmic process to which the moon is necessarily subject. It will be shown that this process is sufficient to account for the principal features of lunar topography.

Before presenting evidence supporting the meteoritic hypothesis of the origin of lunar features, a few of the more conclusive objections to the volcanic theory will be presented. In the first place, the moon is without water and a sensible atmosphere. On the earth, vulcanism is limited almost entirely to sea bottoms and to land bordering the oceans. The process appears to be related to sedimentation and possibly to removal of material by air and water from one place on the earth's surface to another.

On the earth a volcanic crater is usually a secondary feature of a volcanic cone which has been built up by the extrusion of lava. If the crater exists, its floor is generally far above the surrounding landscape. Now, if vulcanism existed on the moon, the resulting cones and their crater floors should be even higher than those on the earth because gravity on the moon is only one-sixth of gravity on the earth. Although relatively low gravity favors the wide scattering of materials on the moon, it in no way interferes with the welling up of more lava to replace that which may have been ejected and scattered.

Thermal and photometric studies of the moon indicate the presence of a blanket of porous material. This fact is consistent with either the volcanic or the bombardment hypothesis.

Careful scrutiny of lunar photographs[1] reveals lunar pits representing activity which dates back a long time and has continued to a very recent geological age. In that portion of the satellite where the pits are more abundant we see superimposed, one upon another, a long succession of forms consisting of some which are so ancient that their battered and buried remains are barely discernible and upon which rest others representing all stages of deformation, even some which appear so fresh that they may have been formed since the Pleistocene age on the earth. The defenders of the volcanic hypothesis have always been faced with the fact that any vulcanism must be dated far back in lunar history. Some attribute its features to the collapsing or explosion of gas bubbles formed on a plastic surface. Evidently no explanation of lunar craters can be satisfactory which does not allow for the

[1] For photographs the reader is referred to the article, "The Surface Features of the Moon" by Dr. Fred E. Wright, THE SCIENTIFIC MONTHLY, Feb., 1935.

process of their formation to continue until recent times.

The unequal distribution of the lunar pits over the surface of the moon has been urged as evidence against the bombardment hypothesis. As a matter of fact, their wide and abundant distribution constitutes a far more serious objection to the volcanic hypothesis than does their unequal distribution against their meteoritic origin.

Except for portions of the *maria* and some of the mountains, no small bit of the lunar landscape has escaped being, at one time or another, a portion of the rimmed pits. And on much of the surface the pits overlap or are contained one or more within another. There is no evidence there has ever been such widespread vulcanism on our planet, where conditions are and have been favorable to it. Far more of the earth's surface is free from lava and volcanic craters than is covered by them. Besides, if vulcanism is to explain the lunar pits, then the *maria* represent enormous lava flows, not only more extensive than any known on the earth, but of such magnitude as to have inundated innumerable rimmed pits of all sizes, traces of which may easily be detected on the best photographs. Judging by the present height of the rims of similar pits outside the *maria*, we must assume that many of these rims rose thousands of feet above the general surface level. Yet, at the present time, the *maria* lie thousands of feet below the average level in adjoining portions of the moon's face. Such an extensive lava flow would, on the earth, require an origin some miles above the periphery. On the moon, because of its smaller surface gravity, it would need to be much higher. Yet measurements reveal no central elevation whatever.

The Battle-Scarred Moon

In presenting the meteoritic or bombardment hypothesis, we deal with a cosmic process within whose domain the moon, no less than the earth, resides. In presuming to treat of this process we are reaching no farther beyond our experience than does the astronomer when he assumes gravity on the moon or the effects of solar heat on its surface. Vulcanism, on the other hand, is strictly a terrestrial process as far as we know, and any attempt to project its activity beyond the confines of our planet must rest upon a clear and unmistakable demonstration that the conditions under which it operates obtain there.

Meteorites are known to bombard the earth at the rate of about one million per hour, of sufficient size to render their courses through the atmosphere visible to the unaided eye. How large these bodies must be in order that their accompanying luminous phenomena (meteors) shall be visible at a distance of 100 miles (the average distance at which we observe ordinary naked-eye meteors) is a matter not yet agreed upon. Formerly, they were considered comparable in size to grains of sand, but recently they have been compared in size to marbles by those astronomers who have given them closest study. It is generally agreed that telescopic meteors are thousands of times more abundant than naked-eye meteors. Dr. C. C. Wylie has recently stated that their number "on the earth per day probably runs into millions of millions."[2]

Of the naked-eye meteors, there is a considerable number of such magnitude that they can be seen in daylight. At night these appear as extremely brilliant fireballs and often detonations are heard by those within twenty to thiry miles of their point of disappearance. Observations through a period of seventeen years have led the writer to believe that from seventy-five to one hundred such falls occur per year within the borders of the United States. Dr. Wylie, who has made

[2] *Popular Astronomy*, 44: 91–2, 1936; University Iowa Obs. Contr. No. 7, 226–7, 1937.

observations in the north-central portion of the United States during almost the same period, has arrived at about the same conclusion. He places the number at ninety per year for the United States and assumes an average weight of ten pounds for them. He worked out a probability curve for meteorites of various sizes encountered by the earth. The following figures are taken from the paper previously referred to (the second item in each statement is mine):

Meteorites of weight ten pounds or more, about ninety per year in the United States. Entire earth, 5,280 per year.

Meteorites of seven thousand pounds or more, two every three years in the United States. Entire earth, forty-three per year.

Meteorites of fifty tons or more, one every thirty years for the land surface of the earth. Entire earth, one in ten years.

Meteorites of two hundred and twenty tons or more, one in one hundred and fifty years for the land surface of the earth. Entire earth, one in fifty years.

Meteorites of fifty thousand tons or more, one in 100,000 years for the land surface of the earth. Entire earth, one in 33,000 years.

It should be noted that the estimates of the naked-eye meteors and of the first item in the foregoing list are based on actual counts. The weights are theoretical, as are all of the items listed, but they agree fairly well with observational data. In cases where there are discrepancies, the observational data indicate that Wylie's estimates are too low rather than too high.

While all the meteorites producing ordinary meteors or "shooting stars" (one million per hour) are destroyed by our atmosphere, each and everyone of this size would actually blast the moon's surface. This fact means that one impact occurs for each square mile approximately every 40 days; or one per square yard every 35,000 years. The surface of the moon would be bombarded by meteorites at an approximately equal rate.

The average velocity of these "marble-sized" missiles is about 26.2 miles per second. No one knows exactly what would be the effect of such an impact, but we do know that a 46-grain metal projectile fired at a speed of 4,250 feet per second (muzzle velocity) against a piece of steel armor plate, explodes with such violence that it blasts a hole in steel plate about one and one-half inches across and one-fourth of an inch deep. The same size projectile fired with a muzzle velocity of between 7,000 and 8,000 feet per second blasts a hole in steel armor two inches deep and two and one-half inches across. It should blast a much larger hole in brittle rock structure. The marble-sized meteorites of the stony variety will compare favorably in mass to a 46-grain projectile. We do not know, however, just what is the ratio between the blasting effects of a projectile traveling at the bullet speeds described and those of meteorites. Applying the rule that the energy of explosion increases as the square of the velocity, we find that the meteorite whose velocity is more than 16 times as great as the highest-speed bullet referred to would be more than 200 times as powerful as explosive as is the bullet. Unquestionably, it would blast a hole in solid rock several feet in depth. Similar impacts are taking place on the surface of the moon; every square yard of its surface receives one of these missiles every 35,000 years, on the average, and nearly 3,000 times in 100,000,000 years, or in relatively modern geological times.

Meanwhile, about 60,000 (estimated) meteorites averaging ten pounds each have landed on each square mile, traveling at similar velocities. Imagine the holes blasted by those invaders whose

weights average more than 2,000 times those of the small ones previously mentioned!

During the same 100,000,000-year period there have been about 500 (estimated) meteorites averaging 7,000 pounds each on every square mile; and on each square mile a mass of 50 tons has arrived to blast a gigantic crater. During the same period, the entire surface of the moon has received about 142,000 meteorites (estimated), averaging 220 tons each and 71 (estimated) averaging 50,000 tons each.

The Lunite Mantle

In view of the blasting action of high-speed bullets and their comparison with even the smallest meteorites, it is evident that the mantle of finely-divided lunite cannot be thought of as being only a few centimeters in depth. The bombardment by meteorites of ten pounds in weight would pulverize the surface to a depth of many feet in comparatively short time, to say nothing of larger impacts. The explosion in and under the mantle would throw that material high, far and wide, because there would be no air resistance and but low gravity to interfere. Much of it would fall back into the pit and be melted along with portions of the sub-mantle to form the level floor which is such a prominent feature of these pits and which led some writers to refer to them as "ringed plains." Many of the pits are marked by cones rising from the centers of their floors. These cones may have resulted from secondary volcanic action which for a time continued as a result of the intense heat generated at the point of contact with the solid sub-mantle. The rimmed pits are very variable in form as well as in size. Some have no level floor and have massive, buttressed walls. Others have expansive level floors and narrow, less elevated rims. The central cones are more prevalent in the former variety. These differences may be due to the types and differences in size of meteorites involved or to the velocities at which they were traveling. A nickle-iron meteorite might pass through the cindery mantle and to some extent penetrate the solid sub-mantle before exploding, which would tend to interfere with the lateral scattering and result in a higher and more massive wall. On the other hand, a very large stony meteorite would explode without any penetration of the sub-mantle and produce a very wide, shallow pit. Its large mass and subsequent heat would fuse all of the material which fell back into the pit and encroached upon the wall, producing a sizeable but shallow lake of lava. As a result of the melting a very great subsidence takes place so that the surface of the fusion pool will be greatly lowered, the amount depending upon the size of the particles and the depth of the material involved. This fact makes very clear the reason why the lunar pits have floors which are lower than the surrounding plain. All of the efforts to explain this depressed interior of the pits in terms of vulcanism have proved to be entirely unsatisfactory; yet this is about their most distinctive feature.

When a large metallic meteorite penetrates the lunite mantle and explodes, it produces a deep pit in the sub-mantle. There are several reasons why a free-flowing volcanic action may be assumed to follow in the central part of the floor of such a pit: Here is the point of greatest heat concentration due to impact; the pool of melt is here several hundred or perhaps thousands of feet deeper than in other parts of the floor and consequently will be slow in cooling; chemical action between meteoritic material and adjacent rocks is likely to develop, giving rise to ebullition; when other parts of the lake have frozen over the central area will continue to boil; as this central area begins to freeze over ebullition will con-

tinue from below and the viscid lava will be spewed out and will build for itself a cone, which compared with those on the earth, will rise, because of the low gravity on the moon, to much greater heights and in much steeper cliffs. The craters, *Archimedes, Autolycus* and *Plato* are examples of those with narrower rims and flat, coneless floors, while *Copernicus, Eratosthenes* and *Aristillus* have more massive buttressed walls, bowl-like floors, and central cones. In certain of the pits there appear, instead of cones, small central craters which seem to be of about the same age as the rims inclosing them. This condition may have been due to a much less protracted volcanic action, more on the order of that which sometimes produces an explosion crater on the earth where a lava flow covers an active vent, temporarily sealing it in, and where finally sufficient pressure is generated to cause it to explode. The same thing might happen under the fusion floor of a lunar pit where the conditions in the depths of the explosion cup were such that its heat was sufficient to cause one good explosion but produced no lava flow thereafter. These secondary explosion craters should be distinguished from impact craters of the ordinary type seen within the larger pits and which postdate the floor upon which they are superimposed. These may appear in any part of the floor or rim of the larger primary crater. *Clavius,* for example, shows four fresh-looking, good-sized craters besides numerous small ones upon its floor and several upon its rim. All these are plainly more recent, however, than is *Clavius* itself. Many other similar instances could be cited.

This brings us to the consideration of the *rays* which so conspicuously reveal themselves at the time of the full moon, when they are seen extending outward hundreds of miles from certain of the pits. They have been shown to have no considerable elevation. They seem to pass uninterruptedly over hills and valleys, pits and rims, alike, some of them extending as far from their point of origin as 1,500 miles! They must either represent mineralogical peculiarities which reach deep into the satellite's interior or must have been laid down in recent geologic time. Otherwise they would have been destroyed by meteoritic bombardment.

Dr. L. J. Spencer has lately suggested an explanation of the rays which seems to deserve serious consideration.[3] He proposes that, when large metallic meteorites exploded, the metallic vapors condensed into minute spherules such as he has found embedded in the fused silica collected around the Wabar, Arabia, and Henbury, Australia, craters. These spherules, because there was no air resistance and very slight gravitational restraint, were shot out to great distances. There being no atmosphere, the bright metallic globules have remained bright and thus give the whitish effect of diffused light. He has called attention to the fact that "the ratio of the number of craters showing bright rays and spots to those without these features is of the same order as the ratio of the numbers of irons and stones that reach the earth." I wish to call attention also to the fact that those "craters" which give rise to the now-visible rays are all fresh-looking craters, indicating comparatively recent formation, while others of the same general form, but older, show no rays. Naturally, the rays may have been there but have been obliterated. We may note also that the rayed craters are all of the deeper, buttressed-wall type, as we have earlier pointed out, and were probably produced by the metallic meteorites which penetrated to great depths.

We come now to the consideration of the *maria,* those relatively smooth areas called "seas" by Galileo who first looked at the moon through a telescope. Here

[3] *Nature,* 139: 655–657, 1837.

have occurred the most phenomenal of all happenings in the history of our satellite. Great areas of lunite as large as the states of Kansas, Nebraska, and Colorado combined were melted down, according to the meteoritic theory, by the collisions of cometary swarms of meteorites. Approximately half of the face of the moon which we see from the earth has undergone this kind of ordeal. It is surprising that Professor Shaler, who rejected the impact hypothesis as applied to ordinary lunar "craters," accepted this explanation of the *maria*. Our explanation differs from his only in certain particulars.[4] Whereas he chooses to account for the phenomena on the basis of an encounter with one body, of planetoidal proportions, in the case of each of the *maria*, I am strongly inclined to consider each *mare* as the result of a collision with a cometary swarm of smaller masses; and whereas he considers it more probable that all of the *maria* were produced at the same time, I am very well convinced that they represent differences in age. Had such a *mare* been produced by the impact of a single body, the mass would surely have penetrated to such depth that we should find evidence of subsequent vulcanism. Huge lava cones certainly would have grown up in the centers of the fused areas and probably at many other points on their surfaces. Such phenomena are notably absent. At first, I sought to ascertain whether *Copernicus* and *Kepler* might represent this kind of process on the plain of *Oceanus Procellarum*. Not only do they fail to show the great elevation above the plain which this interpretation demands, but the ray system of *Copernicus* clearly spreads over much of the surface of *Mare Imbrium*, which is evidently of considerably more recent origin than *Oceanus Procellarum*.

[4] N. S. Shaler, "A Comparison of the Features of the Moon and Earth," Smithsonian Contr. to Knowledge, pp. 1–130, 1904.

Comets are rather abundant in the solar system. It has been fairly well established that their nuclei consist of swarms of meteorites. How large are the bodies that compose these swarms is not known, but we may assume that those of planetoidal dimensions are rare. Let us suppose that a swarm of meteorites a few hundred miles in diameter is composed of various-sized masses up to fifty or one hundred million tons, the total weight of the swarm running into billions of tons. Collision with such a swarm would involve no deeper penetration than would the impacts of solitary masses such as formed the larger "craters," but the fusional action of the various units would coalesce into one great lake.

Cometary encounters, such as may possibly have caused the *maria*, may well be considered as having been responsible on the earth for the puzzling succession of *geological revolutions* which mark the principal time divisions in historic geology.

In our discussion we assume an atmosphereless moon. We are aware that some students believe that the moon has a tenuous atmosphere comparable to that which exists at elevations of forty to fifty miles above the earth's surface. There seems to be a fair way to settle this question. The majority of our naked-eye meteors are at such heights and greater. This fact means that if such an atmosphere were present on the moon, comparable to that surrounding the earth, invading particles would encounter the same resistance as they do at similar elevations above the earth. Therefore meteors should be as bright and numerous as they are here in our atmosphere. We view our meteors from an average distance of about 100 miles. This is well above the observational optical distance at which the moon is ordinarily studied through the largest modern telescopes. Then, surely, the

dark portion of the moon's disk should be an excellent field for observing meteors, if there is a lunar atmosphere. Naked-eye meteors are blazing through our atmosphere at the rate of a million per hour; hence the moon should have a rain of about 70,000 per hour. These should surely present a beautiful display for the telescopic observer, far better in fact, than do ours here in our own atmosphere because we are better situated for seeing a large area at one time. Haziness due to angular penetration of our atmosphere does not bother at all in our vision of the moon. We can choose a time which allows vertical penetration of our own, and if the moon has an atmosphere, we are viewing it from the outside. Consequently, if any meteorites are being consumed there, we should be able to see the resulting light more clearly than we do any but the brighter of terrestrial meteors!

On the other hand, striking the mantle of lunite as their first resistant medium, even though they doubtless do give forth a flash, it could appear as only an instantaneous spark to the observer at the telescope, because they are immediately buried under opaque lunite. Even at the instant of the flash, only large meteorites would produce flashes bright enough to be visible from the earth. Falls might be detected if one were fortunate enough to be looking at the moon at the right moment, but it is probable that craters of a mile or more in diameter have been formed not oftener on the average than once in a thousand years on the entire moon.

In view of the shielding effects of our planet and the absence of any atmosphere pyrotechnically to herald the arrival of meteorites on the moon before they actually plunge into the lunite, we may not look forward with much expectation to witnessing any change on the surface of our satellite. However, it is not impossible that we may do so, and every effort should be made in the direction of the most painstaking scrutiny and the most careful comparison of lunar photographs taken at different dates. The earth acts as a shield against all meteorites whose courses lead them to pass within somewhat more than 200,000 miles of this planet, so that in our time while the moon exhibits no rotation relative to the earth, the majority of its encounters with meteorites are entirely out of our range of vision.

Other Lunar Features

Without attempting to deal with all problems of lunar topography, there are yet some which should be considered. A few (less than one per cent.) of the "craters" have floors which lie above the level of the plain outside their rims and one, a rather large one, in particular exhibits no rim at all but appears as a plateau with steep sides and level summit, as if an ordinary, large, rimmed pit had been filled to the brim with molten material and then cooled in place. This, indeed, is what probably happened. Let us assume that a *mare* plain had been formed and had not yet thoroughly cooled. Its surface had frozen over to a considerable depth, but a large body of molten lunite was sealed within it. At such a stage the *mare* would be in a shrinking condition. Into this frozen-over lake of lava a large meteorite fell. The crust was penetrated, the usual rim was thrown up, but instead of the pit remaining empty it was filled by the welling up of viscid lava due to the pressure of the subsiding plain. Such features are scarce for the reason that large meteorites have fallen so infrequently that they have seldom arrived when exactly the proper conditions existed to produce them.

Much more common features are the small mounds on otherwise level surfaces of the *maria*. These may be a mile

or more in height and twice as wide. They have been termed *laccoliths* by some writers, but a true *laccolith* would presuppose that the conditions requisite for vulcanism existed at the time of its formation. Since the time when true vulcanism may be reasonably assumed to have existed, the meteoritic bombardment must have obliterated all such features. They may very well have been formed by meteorites perforating the crust of a lava lake at an earlier stage when its crust was not so thick and when the lava was more fluid, with the result that a small mound was formed by extrusion, concealing any rim that may have been produced by the meteorite's penetration.

Other mounds show funnel-like openings in their summits as though a bubble in viscid matter had started to collapse. Still others seem to have fully collapsed. These are what might be expected where foreign materials are being intruded, from without, into the lunite. Meteorites carry considerable amounts of chemcially active ingredients. Naturally there will be developed certain chemical activity accompanying the heat of impact. Ebullition will result. Some of the gasses escape, but in some cases pockets or bubbles will form and these may become frozen at any stage on their way to escape at the surface.

The rills and deep gorges which are quite numerous on the moon present something of a problem. Many of the straight, furrow-like structures may be the result of meteoritic encounters in an almost horizontal plane. Others are probably the results of faulting which must of necessity have accompanied the gigantic collisions represented by the larger pits and the *maria*. They must have been produced contemporaneously with the production of other conspicuous lunar features. Otherwise they could not have survived.

WHAT IS KNOWLEDGE?

By Dr. ARCHIE J. BAHM

DEPARTMENT OF PHILOSOPHY AND SOCIOLOGY, TEXAS TECHNOLOGICAL COLLEGE

COMMON sense tells us that the table in our room is colored and solid, has size and shape, is heavy and endures. It exists where it is without depending upon us for its existence. If we left the room and came back later, it would still be there and would have been there all the time, unless, of course, somebody or something had moved it. Our looking at it does not affect it, does not change its nature, does not modify it in the least. Its color, size and shape are really just as we see them. We could feel its weight if we lifted it. Many of us can look at it and all see the same thing. These statements may seem so obvious that it is foolish even to mention them. If one claims they are untrue, he may be considered mentally unsound. Yet, common sense itself leads us to question them and eventually to deny many of them.

NAIVE REALISM

In order to identify the views more or less commonly held by unreflective people, epistemologists have coined the term "naive realism." The naive realist is a "straw man" set up to represent us in our unreflective moments. This straw man is not quite like any of us, for most of us have reflected somewhat. Thus naive realism must be, paradoxically, a reflective statement of an unreflective view. It may be summarized as follows:

(1) Objects are independent of their being known. They can endure or continue to exist without being experienced by any one.

(2) Objects have qualities (properties, characteristics, attributes) which are parts of the objects.

(3) Objects, including their qualities, are not affected merely by their being known. They are neither made nor changed merely by our knowing them.

(4) Objects seem as they are and are as they seem. Appearances are realities.

(5) Objects are known directly, *i.e.*, they are in experience. There is nothing between them and our knowledge of them.

(6) Objects are public, *i.e.*, they can be known by more than one person. Two or more people can see the same object.

Criticisms of Naive Realism

Trouble arises for the naive realist when attention is called to the fact that statements 1 and 5 are incompatible. Objects are independent of experience and yet are in experience. One's experience, knowledge, ideas, are located within one's head. But objects are located outside of one's head. How can objects which are outside of one's head be in experience which is inside of one's head? Trouble arises for the naive realist also when he faces the fact of error. When errors are called to attention, we recognize them and are happy that we have now arrived at the truth. But if asked what assurance there is that the new view is true, we reply that it seems true. But this is the same assurance that we had of the error before it seemed to be an error. Trouble arises for the naive realist in modern times because so much reflection by others has taken place. He is constantly confronted with evidence that the qualities which objects have are conditioned by various factors affecting different people differently and the same person differently at different times. In a world of science, the naive realist has a hard time retaining his naiveté.

Criticisms of naive realism may be classified for convenience under four headings.

(1) *It fails to account satisfactorily for error.* If things are as they seem and seem as they are, then whatever seems to be so is so. Such a view makes error theoretically impossible, for an error is something which seems to be so but isn't so. Recall the common experience of seeing a stick partially submerged in water. Upon first sight the stick appears bent or broken. If naive realism is taken at its face value, then if the stick seems bent it is bent. If the stick is pulled out of the water, it is seen to be straight. Does the stick bend as it goes into the water? Previous experience with sticks and water usually suggests "No." But the stick appears to bend as it goes into the water. What, then, can be done to determine whether the stick is really bent or really straight? For the moment it seems both bent and straight. Since it can not be both, one of the two appearances must be erroneous. The next step commonly taken is to run one's hand along the stick down into the water. To the hand the stick seems straight, even though to the eye it seems bent. The stick is really straight. He dismisses the bent appearance as an error or illusion, and drops the matter. But what are illusions? They are objects which are not as they seem. If some objects are not as they seem, then it is false that all objects are as they seem. If some objects are not as they seem, what makes seeming sometimes "so" and sometimes "not so," and how often is seeming "so" and how often "not so"?

Examples of error trouble the naive realist, but they trouble him little. He goes from conviction to new conviction, confident in the reliability of his newest view. When pressed with the query,

"But how can you tell that your new conviction is more reliable than the one given up as erroneous?" he often answers, "Well, I just know." Or, if you get him in a corner and prod him for an explanation, five kinds of replies eventually come out: (a) He appeals to his other senses for corroboration. (b) He compares with past experiences. (c) He repeats the experiment. (d) He invokes the testimony of others. (e) He appeals to instruments.

(a) If appearances derived through one sensory channel appear contradictory, it is natural to appeal to other senses for corroboration. If a dull ring indicates that the china is cracked, one naturally feels with his finger and looks to see. But sometimes different senses contradict each other and sometimes different senses corroborate in error. When senses contradict each other, which shall be accepted as reliable? The half-submerged stick looks as if bent, but feels straight. The distant carpenter's hammer stroke is seen to stop but heard to continue. When senses corroborate in error, one is still more baffled. Who has not had the experience, in a railway terminal, of having the train start moving? First he feels the rumble of the wheels over the tracks, and hears the movement of the wheels under him, and looks out to check to see if he is at last moving. Then he is shocked to find that not his but the next train is moving.

(b) Comparison of present paradoxes with past experiences involves greater possibilities of error and greater paradoxes. For past experiences, to be compared, must be remembered. But memory often has failed us. How can we be sure that it is not failing us again? And the past experiences themselves might have been erroneous. Can the possibility of erroneous recollection, added to the possibility of erroneous past experience, be used to deny evidence present at hand? Perhaps, however, recollection of experiences repeated in the past many times may be considered more reliable than a single present experience. Yet experiences in the past may have been consistently erroneous.

(c) Doubts sometimes lead to experimentation. Is the bent stick really straight? The naive realist pulls it out and puts it back in several times and feels of it several times to prove that it is really straight. But how can he discount the fact that it also appears bent repeatedly? Also, if past experiences can have been consistently in error, why not present and future experiences?

(d) When doubts about one's beliefs become serious, it is natural to consult others. "Does this stick look bent to you? Feel of it and see if it isn't straight." Gregarious naive realists derive much satisfaction from social corroboration, but they fail to recognize two things. First, their perception of other people as objects which may be consulted is also liable to error. Most of us have mistaken manikins, mirror images and movie motions for real men. Or in dreams we have consulted our friends and gained their agreement. What test is there that there are real people to consult? Secondly, even if we consult real people, are they not subject to the same errors as we? Can not people be in agreement and yet be in error? For centuries people agreed that the earth was flat. If others share our error, what can we profit by consulting them for proof?

(e) The last resort of the naive realist is an appeal to instruments. Heat is measured by thermometers. Weight of purchases is measured on scales. The color of blood is revealed under a microscope. But the appeal to instruments, like the other appeals, is a confession of failure. For it is a confession that apparently obvious objects are not self-evident. And an appeal to instruments is an appeal to reflection. To the extent

that men are reflective they cease to be naive.

Before we let the naive realist out of his corner, let us ask him one more question: "How can you tell that you are not dreaming?" He naturally replies, "I can pinch myself to see if I am awake." "But can you not dream of pinching yourself and convincing yourself that you are awake?" "Yes, but I can ask others if I am awake, and can walk and run and read." "But can you not dream of doing these also?" He is forced to admit, "Yes," but persists in discovering additional suggestions, including that of waking up. But people sometimes dream of waking up and dream of waking up their friends to cooperatively settle their dreaming doubts. If there is nothing in one's waking moments about which one can not dream, and if dreams seem real, then what assurance has one that he is not now dreaming? If he has none, then in how far is he justified in maintaining the truth of his beliefs any more than a dreamer has? How can he tell when he is in error?

(2) *It fails to take into account the extra-organic and intra-organic conditions of knowing.* Some scientists describe the human body as an organism and distinguish for convenience between extra-organic and intra-organic factors, *i.e.*, factors outside the body and factors inside the body. If many factors between the thing causing the idea and the idea itself affect the idea, then the idea may be different from what it would be if it were influenced by the thing alone. Let us consider a few such factors.

Extra-organic conditions of visual perception include light sources, pigments, atmospheric conditions, glasses. Light sources are of many sorts, and what one sees may be stimulated by a single source or many sources, by light of a single frequency or of mixed frequencies, by light of a single intensity or of many intensities, shining from one angle or from many angles. All these make a difference. Some pigments absorb all rays, others none, others some. Atmospheric conditions affect visibility, exemplified by fog, snow, dust, rain and heat waves. Glasses, telescopes, microscopes, their accuracy, their adjustment, their color, all affect perception. Does the real nature of things change as these intervene? Furthermore, the distance which light waves travel is a factor which naive realists neglect. If light travels at a rate of 186,000 miles per second, some fraction of a second is required for transmission from table to eye. So we "see" the table, not as it is when the light wave reaches the eye, but as it was when the light wave left the table. Such fraction of a second seems so insignificant in the total reaction involved in perception that it may be ignored for practical purposes. When distances become great, however, the significance changes. Astronomers astound naive realists with assertions that stars which seem to be up there have long since ceased to be there.

Visual perception is conditioned intra-organically by the complicated nature of eyes. Before a colored table can be perceived, light waves reflected from the table's surface must travel through some medium to the surface of the eye, penetrate the skin, travel through the aqueous humor, the lens, the vitreous humor, to the retina and its rods, which react to variations in light intensities, and its cones, which react to variations in wave frequencies. These cells behave like little chemical batteries or photoelectric cells. When stimulated by light they generate electric currents or nervous impulses which are sent through neurones to the brain. Somehow the brain functions in such a way as to produce attention to, and consciousness of, the object being experienced.

How can color, which the naive realist supposed the table to have, travel on light waves which are merely high-frequency

vibrations, penetrate skin, liquid and lens, then undergo chemical transformation, travel through neurones as electrical impulses, enter conscious experience unchanged?

How can shape, which the naive realist supposes the table to have, be transmitted into conscious experience? Rays traveling simultaneously reach different parts of the curved cornea at slightly different times, travel through a mobile doubly-concaved lens, reach the curved rear inner surface of the eyeball only after being inverted. Then the rays stimulate chemical reactions in the rods and cones; but these may react at slightly different rates, if they are variously fatigued, or some may not react at all. What happens to the supposed shape of the table during these chemical reactions? Then nervous impulses are set up traveling through the optic neurones of different lengths, which twist maze-like on their way to and in the brain. Since we see with two eyes, we really get two sets of patterns of rays. Impulses through the optic nerve split in such a way that those coming from the right half of each eye terminate in the left rear lobe of the brain and those from the left half of each eye in the right lobe of the brain. These lobes seem to be separated from each other by a longitudinal fissure. How can the supposed shape of the table stand such distortion, transformation, duplication and separation without affecting its appearance?

How can size, which the naive realist supposes the table to have, be transmitted into conscious experience? The table-top is three by five feet. But that size can not really be contained within a head wearing a size seven hat. Size too must be transmitted through a tiny hole called the pupil and meander through twisting brain-paths. Not size but, at best, relative size can be perceived.

(3) *It fails to take into account differences in public knowing.* To the previously mentioned extra-organic and intra-organic conditions we may add some which emphasize differences between people. Naive realists believe that two or more persons can see an object at the same time and all see it as it is. Thus all these people can have exactly the same experience. But disputes about objects illustrate differences in experiences. Also, scientific tests have been devised to demonstrate these differences, as for example through colorblind tests and the anomaloscope. The anomaloscope is a system of prisms and lenses mounted in a tube such that one can see through an eyepiece two halves of a lighted circular field, the color and intensity of which are controlled by screw-adjusted slits permitting monochromatic yellow light (589 millimierons) to reflect from one half and a mixture of monochromatic green light (536 mm) and monochromatic red light (670 mm) in any proportion to reflect from the other half. Tests show that when one person has adjusted the anomaloscope so that both halves of the visual field appear equal in color and intensity, another person who looks will object that they appear different and will require readjustment to make the halves appear equal. Thus is demonstrated reported differences in experience when extra-organic conditions of stimulation remain constant. Thus obviously different people may not see the same object as it is, but experience different objects when confronted by the same stimulus source.

(4) *It fails to take into account the "constructed character" of knowing.* The term "constructed character"[1] of knowing may be used to name the synthesizing process that goes on in the brain before experiences are produced. The various nervous impulses do not appear in consciousness to be consciously assembled or constructed into an object. Objects appear in consciousness as

[1] Roy Wood Sellars, "Principles and Problems of Philosophy," p. 52.

wholes. They enter experience already made. Some unconscious or subconscious process determines our conscious experiences for us, even though we can never become aware of it. The mystery of consciousness may never be explained satisfactorily, but it is obvious to those who reflect that something happens within us to make us see things the way we do. This something must be taken into account in explaining the nature of knowledge.

Perhaps the most startling construction is that of consciousness itself. Consciousness seems to be continuous, at least from waking in the morning until going to sleep at night. But psychologists nowadays are inclined to think that consciousness is not a continuum but a series of pulsations, each lasting some fraction of a second. The relative durations of periods of impulses to the durations of periods between impulses vary from person to person and from time to time. Measurement of the length of these pulsating periods of consciousness is difficult and must be done by indirect means. Pulsations of consciousness sometimes correspond to eye-jerks, which pass unnoticed by most readers. One sees the line of printed words he is reading as a continuous line, but if he observes another reader's eyes he will note that eyes do not move continuously but stop, flick, stop and flick. If consciousness is a series of impulses, why do we seem to be conscious continuously? In order to be conscious of the period between moments of consciousness we would have to be conscious when we are not conscious. This is impossible. We can experience neither the period between, nor the ending, nor the beginning of a flash of consciousness. In order to experience the end of a flash, we should have to be conscious long enough to include the end within consciousness, which again is impossible. In order to experience the beginning of a flash of consciousness, we should have to be conscious already and to include the beginning of the flash of consciousness within consciousness. Thus the illusion of continuity of consciousness is a basic illusion without which experience could not be. The naive realist can not believe this.

Another basic construction is the construction of "objects." Objects seem to be "out there," even though they are not really out there as experienced. One may try the experiment of looking at his own hand, which he usually considers a part of himself. His hand seems to be out there. Try again to look at the tip of his nose. It too seems out there. Try again, with eyes closed, to imagine his own brain. If he can imagine it, the image of it too seems to be out there, not as if in the room before him, but still as an object out there in experience.

Taking leave of naive realism, we may summarize the types of criticism offered. It fails to account satisfactorily for error. It fails to take account of the extra-organic and intra-organic conditions of knowing. It fails to take into account differences in public knowing. It fails to take into account the constructed character of knowing. If these criticisms are warranted, then naive realism is untenable. The naive realist is baffled by them. But the natural urge to believe that things are as they seem is so strong that in practice he is little troubled by them.

Scientific Realism

If naive realism is untenable, then what view shall one hold? Skipping over many steps which one would normally take in the gradual process of reflection and many steps which have been taken historically in the development of reflective thought, we may summarize a view called "scientific realism." Like the naive realist, the scientific realist is also a straw man set up to represent the point of view which "the" scientist would hold

if all the assumptions and conclusions of the different sciences were synthesized into a single view of the nature of knowing. Comparing scientific realism with naive realism (see p. 1), we may summarize comparable essentials as follows. Basic throughout is a distinction between what we shall call real "things" and apparent or experienced "objects."

(1) "Objects" are dependent upon their being known; they can not endure without being experienced. "Things" are independent of their being known; they can endure without being experienced.

(2) "Objects" have qualities (properties, characteristics, attributes) which are parts of the "objects" (but not parts of "things"). "Things" have qualities (properties, characteristics, attributes) which are parts of the "things" (but not parts of "objects").

(3) "Objects" (including their qualities) are affected by, are dependent for their existence upon, are determined in their nature by, their being known. "Things" (including their qualities) are not affected merely by their being known.

(4) "Objects" seem to be real "things" but are not real "things." "Things" are not as they seem to be. Appearances are not realities and realities are not appearances.

(5) "Objects" are known directly; they are in experience. "Things" are known indirectly; they are not in experience; they are known only through "objects" which "represent" them, and which are caused by them and by other extra-organic and intra-organic conditions which happen to operate conjointly with them.

(6) "Objects" are private, *i.e.*, can not be known by more than one person. "Things" are public, *i.e.*, may be the cause of "objects" in more than one person.

Criticisms of Scientific Realism

Satisfactory as this view may seem to scientists, there are certain criticisms which should be considered.

(1) *Scientists also depend upon senses for information.* Like naive realists, scientific realists also get their experiences only through sensory channels. The scientist still seems to see the half-submerged stick as bent or broken. Each of his types of perception is equally liable to error. Thus scientific conclusions, in so far as their reliability depends upon the reliability of perception, are subject to the same criticisms as naive realism.

Price's way of putting this criticism is worth repeating.

> Every man entertains a great number of beliefs concerning material things, *e.g.*, that there is a square-topped table in this room, that the earth is a spheroid, that water is composed of hydrogen and oxygen. It is plain that all these beliefs are based upon sight and on touch (from which organic sensation can not be separated): based on them in the sense that if we had not had certain particular experiences of seeing and touching, it would be neither possible nor reasonable to entertain these beliefs. Beliefs about imperceptibles such as molecules or electrons or x-rays are no exception to this. Only they are based not directly on sight and touch, but indirectly. Their direct basis consists of certain other beliefs concerning scientific instruments, photographic plates, and the like. Thus, over and above any intrinsic uncertainty that they themselves may have, whatever uncertainty attaches to these more basic beliefs is communicated to them. It follows that in any attempt either to analyze or to justify our beliefs concerning material things, the primary task is to consider beliefs concerning perceptible or "macroscopic" objects such as chairs and tables, cats and rocks. It follows, too, that no theory concerning "microscopic" objects can possibly be used to throw doubt upon our beliefs concerning chairs or cats or rocks, so long as these are based directly upon sight and touch. Empirical science can never be more trustworthy than perception, upon which it is based; and it can hardly fail to be less so, since among its non-perceptual premises there can hardly fail to be some which are neither self-evident nor demonstrable. Thus the not uncommon view that the world which we perceive is an illusion and only the "scientific" world of protons and electrons is real, is based upon a gross fallacy, and would destroy the very premises upon which science itself depends.[2]

[2] H. H. Price, "Perception," p. 1.

(2) *Scientific concepts are human constructs.* While scientific realism attempts to take into account the fact that knowing involves some mysterious subconscious synthesis, nevertheless it can not prevent its own concepts from being thus mysteriously synthesized or constructed. Every scientific idea is a human idea, is an idea limited by the peculiar limitations inherent in the mind or minds of those who entertain it. Some scientists who are especially self-critical cease to be scientific realists. This critical attitude is exemplified by P. W. Bridgman's "The Logic of Modern Science." The laws of physics, like all scientific laws, are merely "operational ideas" which serve to explain in what way, though not why, events occur in experience. In how far regular occurrences represent real events outside of experience is not the business of science to say. Such a view seems to scientific realists as a thin pale shadow of science, not one which gives us the knowledge of reality that scientists believe they are looking for. Yet, if scientists believe they can penetrate reality, can they explain how they can do it with ideas which are subconsciously constructed and which have their momentary existences locked up within flashes of pulsating consciousness?

(3) *Scientists still have no better tests than dreamers.* This charge at first shocks scientists as absurd. But, for every test that a scientist proposes for his being awake or for the reliability of his conclusions, one may ask, "Is it impossible for him to dream that this is so?" Surely he must answer "No" and thereby admit the impossibility of proving his position any better than a dreamer might.

(4) *Scientific realists unwittingly claim impossible transcendence.* Admitting that "objects" are private, scientific realists themselves fall into the egocentric predicament. Only private "objects" are experiencible. How then is it possible to know either that there is an unexperienced real world or what it is like? When scientific realists claim that they know that there are public "things" and that they are electrons, atoms, molecules, etc., they claim to know the existence of and, within limits, the nature of unexperiencible things. How can knowledge which is locked up, so to speak, within moments of conscious experience transcend those moments and reach out, so to speak, into the unreachable real world to know it? Knowledge of reality seems to presuppose experience of the unexperiencible. To be real is to be independent of experience, so inherent in scientific realism is the necessity of experiencing what, by the very nature of experience, can not be experienced.

(5) *Scientists still fail to explain why "objects" appear as if they were "things."* The mystery of why appearances seem real remains a mystery to the end. The scientific realist is beset with a belief in the reality of the objects he talks about. Even though he is constantly critical, can he ever conceive a real atom without conceiving it as real? Why, if one's conceptions continue to be within him, does he conceive objects as if they were really "out there"?

No attempt has been made in this article to give any final answer to the question, "What is knowledge?" Two types of answers have been presented and criticized. It is hoped that the reader has been aroused sufficiently to investigate other types of answers such as rationalism, idealism, scepticism, agnosticism, critical realism, neo-realism, pragmatism, positivism or the author's proposed "tentative realism."

RESPONSES IN AN ASSOCIATION TEST

By the Late Dr. RUDOLF PINTNER

FORMERLY PROFESSOR OF EDUCATIONAL PSYCHOLOGY, TEACHERS COLLEGE, COLUMBIA UNIVERSITY

THE association test in psychology consists of the presentation of a stimulus word which elicits another word as a response from the subject. It is probably one of the very oldest of psychologist's tests. It has been used in abnormal, criminal, educational and business psychology in many ways.

In 1933 this writer reported in this journal[1] the responses of students to the stimulus, "Think of the name of a president of the United States." This was one item in a written group association test given annually to groups of students, beginning in 1925. This test has been continued, and we now have results from 1925 to 1941 for 6,071 individuals.

TABLE I

RESPONSES TO THE STIMULUS "THINK OF THE NAME OF A PRESIDENT OF THE UNITED STATES"

Response	Number	Per Cent.
Washington	1,343	22.1
Roosevelt	1,288	21.2
Lincoln	856	14.1
Wilson	820	13.5
Hoover	538	8.9
Coolidge	429	7.1
Harding	176	2.9
Grant	95	1.6
Jefferson	90	1.5
Adams	73	1.2
McKinley	69	1.1
Taft	53	0.9
Cleveland	50	0.8
Garfield	45	0.7
Jackson	40	0.7
Monroe	27	0.4
Madison	16	0.3
Harrison	12	0.2
Johnson	8	0.1
Hamilton	5	0.08
Hayes	5	0.08
Polk	5	0.08
Van Buren	5	0.08
Buchanan	4	0.07
Taylor	4	0.07
Arthur	3	0.05
Pierce	3	0.05
Tyler	3	0.05
Fillmore	2	0.03
Franklin	1	0.02
Lee	1	0.02
No Response	2	0.03
Total	6,071	100.01

[1] R. Pintner, SCIENTIFIC MONTHLY, 36: 523–526, June, 1933.

The main conclusions in our previous article seem to be borne out by the data accumulated since it was written, and some of the suggestions offered then have been strengthened, as we shall see.

Table I shows all the responses made by the 6,071 individuals. Practically all these were college students, with the exception of 385 W.P.A. workers tested in 1937, most of whom had no college education. The list in Table I includes all the presidents of the United States, and in addition three famous men who have not been president: namely, Hamilton, Franklin and Lee. The two latter have been mentioned only once each, but Hamilton is named more frequently than several actual presidents. In this test it is not possible to distinguish between two presidents having the same family name, as in the case of the two Roosevelts, the two Adamses and the two Harrisons.

The whole list falls into three divisions. At the top we have the first four most frequently mentioned, accounting together for 70.9 per cent. of the responses. Then we have three presidents very recently in office, two of them actually in office during some of the years this test was given. These three responses account for 18.9 per cent. of the total. Down to this point, therefore, the first seven responses are responsible for 89.8 per cent. of all responses. After these we have the long list of other responses, no one of which amounts to more than 1.6 per cent. This long list of "also rans" accounts altogether for only 10.2 per cent. of the total responses.

Three main factors seem to me to be at work in explanation of the most common responses, that is, the first seven names on our list. One factor is that which

causes the great majority of the common responses in all our association tests; namely, the habits formed in hearing, reading, speaking and writing. One word is linked to another because of these habits.[2] This is very likely the main factor at work in the responses "Washington" and "Lincoln." These two names have been linked to "president of the United States" on countless occasions, and they emerge promptly at the given stimulus.

Another factor at work is recency. Although by no means as strong as the preceding factor, it explains some responses in all association tests. If we have just been reading the life of Henry VIII of England, we may write the word "Henry" to the stimulus word "king" in an association test, although the most common response by force of habit to this stimulus word is "queen" (50.1 per cent. of all responses in my test). With reference to our presidents, this factor of recency is potent in the responses "Hoover," "Coolidge," "Harding" and to some extent "Roosevelt." Three of these individuals have been in office during the time the test was being given, and one, Harding, just previous to that time. Recency is also very probably one of the factors at work in the response "Wilson," but another more potent factor, to be discussed presently, is also at work. The effect of recency can be seen most clearly in the responses "Hoover" and "Coolidge." Here are the average annual percentages for the years in office and for the succeeding four-year periods:

	1925–28	1929–32	1933–36	1937–40
Coolidge	16.5	5.2	3.2	1.5
Hoover	.....	21.2	8.4	4.7
Roosevelt	4.6	3.4	38.3	48.0
n	1,654	1,866	630	1,669

The response "Roosevelt" is complicated. As we can see from the above, a small percentage of the responses refers to Theodore Roosevelt. The sudden increase in percentage during the incumbency of Franklin D. Roosevelt is due to a combination of recency and another factor.

This brings us to the consideration of the third main factor. This is the feeling tone or emotional aura surrounding a given stimulus. For example, if one feels keenly about the danger of drinking alcoholic beverages, the response to the stimulus word "whiskey" may be influenced by this emotional setting. In my experiment about 1.6 per cent. of the responses seem overtly to indicate a strong feeling against whiskey. Such responses are "bad," "harmful," "poison" and the like. Not all strong emotional tone issues in such overt responses, so that it is impossible to measure it with any degree of accuracy. Ordinarily this factor of emotional tone is the weakest of the three influences we have described.

The influence of this factor upon two of the responses to "president of the United States" seems to me to be nicely demonstrated in the responses "Wilson" and "Roosevelt" during the years 1925 to 1941. During the lifetime of most people now living, no other presidents have stirred up so much emotional agita-

[2] E. L. Thorndike, *Jour. Applied Psychol.*, 16: 247–253, 1932.

TABLE II

CUMULATIVE PERCENTAGES OF RESPONSES TO "PRESIDENT OF THE UNITED STATES" MEAN FOR EVERY TWO YEARS

	25–26	27–28	29–30	31–32	33–34	35–36	37–38	39–40	41
Roosevelt	5.8	4.3	4.1	3.9	5.0	9.1	16.1	19.9	21.2
Wilson	22.6	21.1	19.9	18.4	17.9	16.7	15.1	14.1	13.5
Washington	27.2	27.7	26.1	25.1	25.2	24.4	22.9	22.5	22.1
Lincoln	13.7	15.6	16.0	15.7	15.4	15.0	14.2	13.8	14.1

TABLE III

CUMULATIVE PERCENTAGES OF RESPONSES TO "AN OUTDOOR GAME" MEAN FOR EVERY TWO YEARS

	25–26	27–28	29–30	31–32	33–34	35–36	37–38	39–40	41
Tennis	32.5	35.4	34.6	33.8	33.7	33.2	33.5	33.4	32.8
Baseball	27.6	29.2	28.6	30.0	29.6	29.3	28.9	28.5	28.9
Football	14.9	10.9	12.2	12.0	11.9	12.1	11.4	11.6	11.6
Golf	8.1	9.0	9.5	9.4	9.4	9.2	9.2	9.0	8.7

tion as these two men. In the case of each of them, many people feel keenly. They "take sides," either for or against. They either love or hate. With Wilson this effect is on the wane; with Roosevelt it is at present very strong.

This waxing and waning can be seen in Table II. This table gives the cumulative percentages; that is, the percentages of the total number of responses up to and including any given year. These cumulative percentages were calculated every year. In order to condense the material, Table II shows the mean of these percentages for every two years (except for the last period, 1941). The response "Roosevelt" is stationary until 1933–34, and then begins a spectacular rise—spectacular because the percentage of such responses has to overcome the load of non-Roosevelt responses accumulated prior to that period. The two factors of recency and emotional tone continue to boost the percentage in 1941 up to the stable "Washington" response, which has been steadily accumulating during the whole period. The response "Wilson" shows a steady decline from a high point in 1925–26, due to the rapid waning of emotional tone. Contrasted with these two responses which show marked changes are the responses "Washington" and "Lincoln," which have remained practically stationary during the whole period. The primary factor at work here is undoubtedly the first fact described, namely, habitual association between stimulus and response.

This analysis of the responses to one stimulus word over a period of years has been chosen to show how contemporary happenings may influence our associative trends. The association test may act as a sort of miniature social barometer. As a contrast to the ups and downs in the responses to the stimulus "president of the United States," I give in Table III biennial cumulative percentages of the responses to the stimulus "think of an outdoor game." Here the forces of associative habit have reigned supreme during the whole period. Nothing has happened to group thinking about this stimulus to interrupt the common habitual type of response. An individual here and there in the group may be influenced in regard to his particular reaction because of recency or emotional tone, but the group as a whole from year to year shows no such influence. The four typical outdoor games for adults in this country at this time are the four listed in our table.

This stability of group responses from year to year is the outstanding characteristic for most stimuli in the usual association test. The forces of habit are very similar for most individuals in a country such as ours, and this similarity leads to a surprising uniformity in the frequency of responses from year to year. The changes in frequency, which we have noted in connection with the responses to "president of the United States" are indicative of wide-spread factors at work among many individuals in the group. The emotional factor may at times become as potent as or more potent than the habit factor, as we have noted in the response "Roosevelt," but the habit factor is there ready to take over as soon as the emotional tone decreases.

BOOKS ON SCIENCE FOR LAYMEN

THE LIFE OF NATHANIEL BOWDITCH[1]

THERE has been no time in the past when so many young Americans were being taught the principles and practices of navigation. It does not make much difference if these students are aimed at the Navy, the Merchant Marine, or the Aircorps, for they will before long all meet up with the mythical volume "Hydrographic Office Publication No. 9" or "Bowditch's American Practical Navigator." The name of Nathaniel Bowditch has become a legend in the annals of American navigation and it is fortunate indeed for the young scholar, as well as for his instructor, that there is now available an authoritative biography of the life of the man whose name has become a household word in navigation.

Nathaniel Bowditch was born in Salem, Massachusetts, in 1773, the fourth child in a family of seven. His father, Habakkuk Bowditch, was, as Mr. Berry puts it rather nicely, "remembered by his pastor for two things; his knowledge of the Scriptures and his extraordinary consumption of rum." Life was not easy for the Bowditches. For a while they lived in a little house at Danvers, a few miles outside of Salem, but they returned to Salem again, and it was in Salem that Bowditch grew up to become one of the most respected citizens of his country. At the age of twelve Nathaniel Bowditch went to work as an apprentice clerk in a ship's chandlery. He received little formal schooling, but with the aid and encouragement of the apothecary, Nathan Read, and two of the local ministers, he succeeded in training himself thoroughly in mathematics and navigation. When, in 1795, Bowditch went to sea he had already acquired a knowledge of mathematics that was equal to that of any other man in the colonies at that time. His first trip as a supercargo on Captain Prince's *Henry* took him to the "Isle de Bomton" (now Réunion), and it was on this journey that Bowditch's interest in the practical side of the art of navigation was awakened. Other journeys took him to the East Indies and to the Philippines, in the beginning again as a supercargo, later as the captain of his own ship.

Urged on by the publisher Edmund M. Blunt, Bowditch was led to correct and edit an American edition of John Hamilton Moore's "The Practical Navigator." Bowditch found this volume to be so full of errors that it would have been folly for a captain to chart his course with the aid of Moore's volume. Bowditch wished to create a book of his own, one that would be literally free from errors and so written that every sailor could understand and use it. It is told how Bowditch tried out his scheme on the crew of one of his ships and progressed to the stage where every member of the crew, including the cook, knew how to determine his ship's position from celestial observations. Bowditch's "The New Practical American Navigator" became right away a popular volume and it was not long before a copy was to be found in the chest of every seafaring man.

The word of Bowditch's fame had begun to spread. In 1799 he was elected a member of the American Academy of Arts and Sciences and in 1802 he received the honorary degree of Master of Arts from Harvard University. His career as a sea captain ended in 1803, with his spectacular landfall and safe arrival during a snowstorm in the harbor of Salem on the evening of December 25th, an incident that will always remain a classical example of the use of "dead

[1] *Yankee Stargazer. The Life of Nathaniel Bowditch.* Robert Elton Berry. Illustrated. xi + 234 pp. $2.50. 1941. Whittlesey House.

reckoning'' by a great navigator. At the age of thirty Bowditch could look back on an honorable career at sea. He was the acknowledged master navigator and his reputation as a mathematician was great.

For us of the twentieth century it is not easy to understand why Bowditch chose at this stage a career in the rather dull and prosaic field of marine insurance. For almost two decades in Salem, and after that until his death in 1838 in Boston, he was during the daytime a skillful executive in marine insurance and at night a mathematician by avocation. His mathematical efforts were mainly concerned with the translation of Laplace's monumental ''Mécanique Céleste.'' His was much more than a simple translation for Bowditch, with his meticulous care and keen analytical mind, added many explanatory notes to the original manuscript. And yet when one reads of Bowditch's life, one can not help but feel some disappointment that the young man of thirty did not see before him a grand opportunity as a creative scientist. Perhaps Bowditch did not have great creative powers and his strength may well have laid wholly in his very special analytic ability. We can, however, only regret that Bowditch in the second half of his life did not attempt to be himself one of the great men of mathematics or astronomy rather than to have remained the brilliant interpreter of those who came before him.

Mr. Berry has written a good book; I would almost say that it is as carefully written as Bowditch would have liked to see it done. There is little reason to doubt the accuracy of its sources; it is fully documented and well written. The only criticism that I wish to make is that the book in spots lacks warmth and understanding. One might almost have wished that occasionally Mr. Berry could have let himself go and that he might have forgotten about historical accuracy to tell us more about why at the age of thirty Bowditch chose to lead what seems to a twentieth century astronomer a prosaic life when the heavens were opened before him!

B. J. Bok

A BIOLOGIST LOOKS AT MAN[1]

This book, covering a wide range from Philosophy to Sociology through Endocrinology, Religion and ''Sex,'' should be of interest to the general public, if not to the professional psychologist. The thesis of the first chapter appears to be that biology should take over the field once known as ''social psychology.'' This suggestion is quite in line with the original meaning of the word *bios*, which signified ''life'' in the social-economic sense, not the zoological. Now that ''social psychology'' has become disreputable because most of the group which, up to December 7, 1941, called themselves ''social psychologists'' were unable to understand the forces which had been for nearly fifteen years preparing this war, and busied themselves with trifling problems, this might be an appropriate time for non-psychologists to take over the field.

The defense of science in the second chapter seems to the reviewer needlessly to place science in the prisoner's dock; but wisely avoids critical points and follows conventional lines, although the author lays himself open to question by claiming social progress in matters such as child labor and the status of women as scientific accomplishments. The question would be: What science?

The third chapter, on ''Man's Place in Nature,'' leads through a review of anthropological and zoological data, up to a sound and well-formulated rebuke to those who have regarded man as an infinitesimal speck in the vast universe.

[1] *Speaking of Man: A Biologist Looks at Man.* Michael F. Guyer. 321 pp. $3.50. October, 1942. Harper and Brothers.

The fourth chapter, on "The Rise of Intelligent Behavior," is a somewhat hasty survey of the field which is commonly called physiological psychology, taking account to some extent of the progress which psychology had made in this field from the traditional basis of assumptions and theories inherited from the physiologists. The fifth chapter, on "Managing our Minds," is a venture into the field of adjustment psychology, implemented from popular psychology and pseudo-psychology. The sixth chapter, on "The Endocrine Control of the Body," appears to the reviewer to be an excellent presentation, by an expert, of important physiological aspects of endocrine function. In considering the effects of hormones on the emotions, the author neglects, as do most endocrinologists, the effects of emotions on the endocrine balance—a topic which is becoming more and more important to psychologists in the field of adjustment.

The seventh chapter deals with "sex" in the confused meaning of that multivalent term which is usual in psychoanalytic and other popular disquisitions. As in most popular articles and books on sex a limited selection of facts is put before the reader, who (if a layman) is not able to supply the omitted material which is necessary for interpretation, or to distinguish the fact from the fiction.

The last three chapters deal with "Democracy as a Biological Problem," "The Educated Failure," and "Man's Search for the Ideal." Although nothing is presented in these chapters which would not be familiar to the educated layman, the author's selections of doctrines and arguments are clearly presented and should be interesting to readers not too sophisticated. The last chapter includes a defense of religion, with misconceptions of certain religions cited, and a defense of a theory of evolution. The form of evolution defended is not clearly indicated; but so far as the reviewer can judge, it is the popular theory which makes evolution analogous to the slow filling-in of the words of a cross-word puzzle, the definitions for which are assumed to have been fixed, unchangeably, in the beginning of the world.

There are some points which might be questioned as regards their validity, their implications or their consistency with other statements, but the reviewer does not feel inclined to criticize details in a popular book.

KNIGHT DUNLAP

FACTS AND THEORIES ABOUT BIRD MIGRATION[1]

OF all the aspects of bird study, migration is probably still the one that interests the greatest number of observers, and in spite of the vast amount of observational data on record, is still one of the least solved, most obviously mysterious of all bird behavior problems. The fact that, in war-torn England, a revised edition of Thomson's compact little book should be issued (and it would not be published unless there was an assumed demand for it) is a clear indication of migration's continuing interest for natural-history minded folk. The book is essentially a reprinting of the first edition of 1936 with very few minor changes and additions (for instance, it has thirteen maps as compared with ten in the first edition). The type is smaller and the number of pages correspondingly reduced from 224 in the 1936 edition to 192 in the present one. [A publisher's note on the back of the fly leaf states that, "the paper and binding of this book conform to the authorized economy standard."]

The book is divided into four main parts, each containing three chapters. They are: 1. Introduction to Migration, with accounts of the study of migration, the different types of migratory be-

[1] *Bird Migration.* A. Landsborough Thomson. Revised edition. 192 pp. 6/–. 1942. H. F. & G. Witherby, Ltd. (London).

havior, and the phenomenon of migration in its broad aspects; 2. Certain aspects of migration, with discussions of the directions, the seasons, and the methods of migration; 3. General Features of Migration, involving accounts of immensity, its complexity, and its regularity; and, 4. Theories about Migration, with the discussion grouped under the topics of the utility and causes of migration, and the mechanism of guiding during migration.

A book of this sort and size is designed for the general reader, and not for the advanced student. In this it is very successful and merits a new edition. It is characterized by accuracy and critical caution, and should serve, as did its predecessor, to give information and pleasure to a large number of people.

HERBERT FRIEDMANN

THE AMATEUR SCIENTIST IN PHILADELPHIA[1]

THE money profit motive has been overemphasized in this modern world. Human beings do not do things primarily for dollars. They do them because they are interested in them and want to do them. Much of the important work of the world is unpaid in cash but paid in pleasure.

The American Philosophical Society's Committee on Education and Participation in Science, with grants from the Carnegie Corporation, carried on for three years one of the most exciting inquiries and demonstrations of recent years concerned with the public participation in science, not as spectators but as practitioners. W. Stephen Thomas, who steered this experiment, tells the story of its success and its background in "The Amateur Scientist."

In Philadelphia, rich in scientific history, fortunate in educational and scientific institutions and museums, and mellowed by an atmosphere conducive to contemplative inquiry, there were discovered by Mr. Thomas some 32,000 scientists-for-the-fun-of-it with societies and informal groups that number nearly 300. We hear much about the professionals, the professors, the science taught in school and college, but we have heretofore heard little about the amateur. We are prone to forget that Benjamin Franklin, whose influence hovered over almost everything scientific in the City of Brotherly Love, was an amateur in science although certainly no novice.

A quartette of specialists, a helpful committee and a small central staff brought to light and gave some stimulation and unity to these serious hobbyists. There were sample and demonstration research projects: When the wild flowers bloom; what tree rings show about the climate of the past; how to mark snakes, frogs and turtles to keep tab on them; and how to probe the upper atmosphere with radio waves. There was sufficient prospecting and assaying to show that there is much scientific gold in those nights, days-off, and Sundays of the expert amateur in science.

You would expect school teachers, pharmacists, physicians, chemists, engineers, to be amateur scientists in Philadelphia, but would you have guessed that there were bankers, business executives, clerks, mail carriers, printers, pattern makers and a hundred other occupations among them, including a professional dancer, housewives by the score, those who have retired and some unemployed?

This extensive interest in science as a serious hobby is not limited to the type city of Philadelphia. Probe beneath the surface of any city or town and you will be sure to find enthusiastic and competent scientific amateurs. The Philadelphia story demonstrates that this is a neglected field, worthy of cultivation by a local institution that has motivation and resources to activate, counsel and guide the latent or unorganized abilities.

[1] *The Amateur Scientist.* W. Stephen Thomas. Illustrated. 291 pp. $3.00. 1942. W. W. Norton and Company.

Professional societies in various fields would be highly justified, in the future when peace gives them time, to integrate this work with their present professional activities, cooperating in a national movement. The way has been blazed for the future by the Philadelphia experiment.

The encouragement of amateur science for adults is as important as the stimulation of scientific hobby activity in the high schools, which is well under way by the national organization of Science Clubs of America administered by Science Service. If the appreciation and understanding of science and its methods can be brought to the attention of the millions as they go through grade schools, high school and college, if they have the opportunity of actively carrying on their interests in later life, even if they choose other means of earning a living and serving the world, then there is a good chance that the world will conduct its affairs more sanely as the number of scientifically oriented people in it increase.

Here is a practical blueprint for future activity when the war is won and we begin to win the peace. Whether we get a chance to build it will depend upon how soon we can start and with what vision and enthusiasm we begin this mobilization of science for all who volunteer.

WATSON DAVIS

HUMANIZING SPIDERS[1]

In the forenoon of September 22, Spinoza died.

This Spinoza was not a philosopher, but a tarantula. In company with Beautiful Lady, Silver Queen and other spiders with personalities, she is described and discussed by Miss Emans in this entertaining book.

There are nineteen chapters, beginning with the time when Miss Emans became snared by spiders, with notes on anatomy and on behavior, based on long hours of careful observation of numerous individuals, some at liberty in the garden and house, others confined to observation quarters. There is a chapter on their economic value and another on their enemies, the most commonly observed of which is the neat housewife with the long-handled broom, annoying the author, who admires the finer qualities of spiders.

The book is nicely illustrated by photographs and pen and ink sketches. A short chapter, "Oddities and Ends," concludes what is an informative and readable account of a group of our much misunderstood neighbors.

W. M. MANN

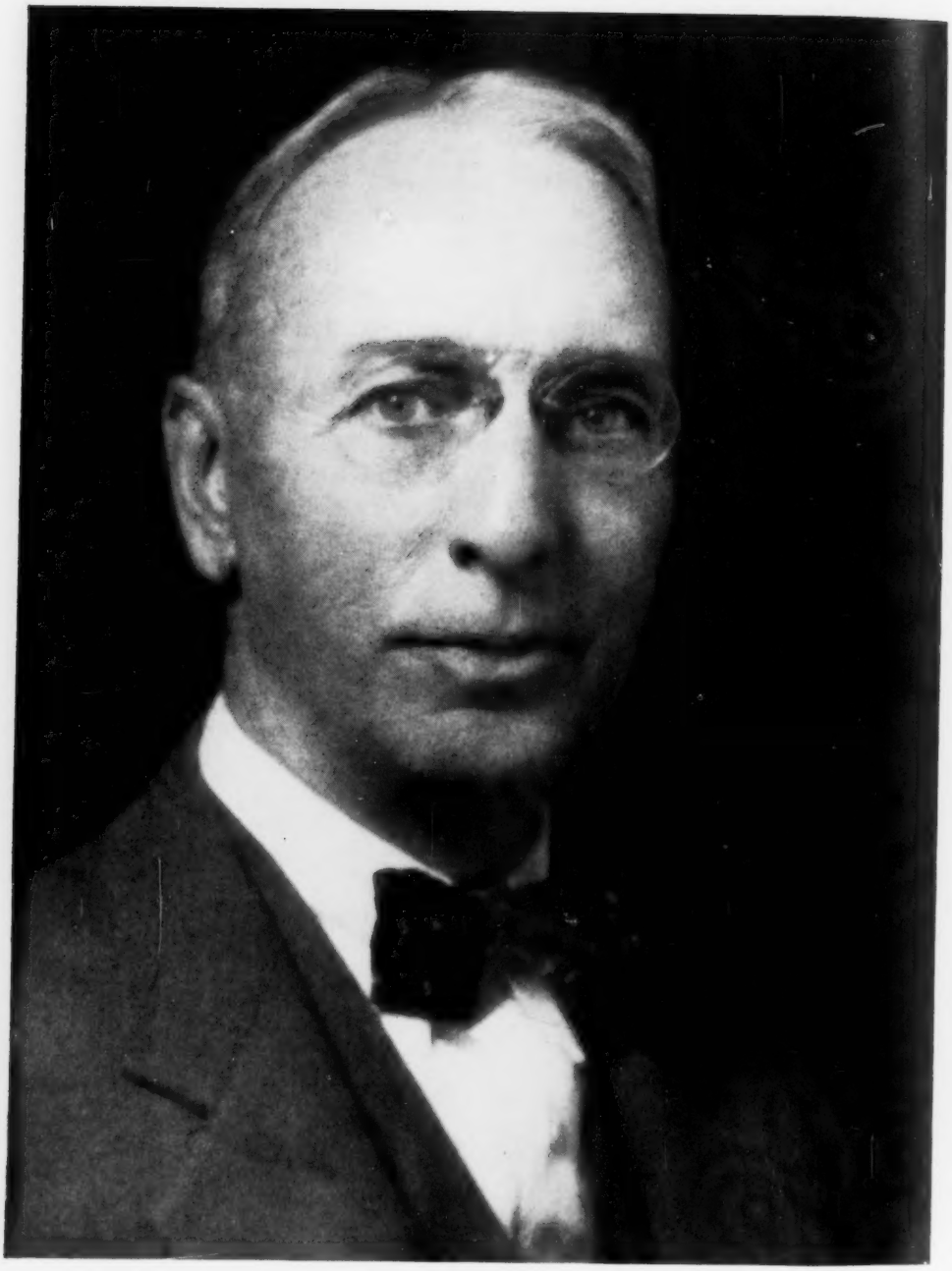
A SURVEY OF BIOLOGY[1]

THIS book is exactly what its sub-title indicates—a survey of various fields of biology. The material which it covers is arranged in a series of chapters, each of which attempts to discuss one branch of the field. The author has succeeded very well in relating the separate fields and in showing the bearing which each has on the others. Although such treatment is bound to be somewhat disconnected, as a survey this book is to be recommended, for it covers many fields and it presents an immense amount of material in a relatively small space. It is put out by planograph, and some of the pictures which would be excellent as photo-engravings are not any too satisfactory, but the wealth of line drawings and diagrams is a real addition to text material. Its value as a text depends entirely on the way one evaluates survey courses in general.

D. B. YOUNG

[1] *About Spiders: Introducing Arachne.* Elaine V. Emans. Illustrated. xix + 183 pp. $2.50. 1940. E. P. Dutton and Company.

[1] *Life Science.* M. W. de Laubenfels. Illustrated. i + 320 pp. $3.75. 1941. Laubenfels.



GARY NATHAN CALKINS

THE PROGRESS OF SCIENCE

GARY NATHAN CALKINS, 1869–1943

THE death of Gary Calkins on January 4, 1943, removes yet another of the "old guard" of science from our midst. Not only was he scientist in the best tradition, but also a man who attracted hosts of friends, so that his passing is a deep personal loss to many, both old and young.

Indiana was his native state, but he spent his student days at the Massachusetts Institute of Technology, where he graduated in 1890 in biology with the degree of B.S. Thereafter his life was devoted to a scientific career. Under the influence of William T. Sedgwick he early became interested in the Protozoa, especially with reference to their part in pollution of water supplies, and was assistant biologist to the Massachusetts State Board of Health from 1890 to 1893; during the same period he was also lecturer in biology at the Massachusetts Institute of Technology. In 1893 he transferred as a student of Edmund B. Wilson to Columbia University, which became his professional home for life from the time of his arrival there. Appointed tutor in biology in 1894, he passed rapidly through the academic grades to that of professor in 1904. In recognition of his ruling interest he was given the special title of Professor of Protozoology in 1906, the first to receive the title in America. He retired as "emeritus in residence" in 1940. Columbia University conferred the honorary degree of Sc.D. on him in 1929 in addition to the Ph.D. degree in 1898. Among other honors he was elected member of the National Academy of Sciences in 1919.

Following his preoccupation with public health problems at the Massachusetts Institute of Technology, which terminated in 1893, the influence of Edmund B. Wilson, the great master of "the cell in development and inheritance," diverted his interests to problems of karyokinesis with special reference to spermatogenesis in the earthworm (1895) and later in the large marine phosphorescent protozoa, Noctiluca (1898). The latter study marked his return to Protozoa, but now mainly on account of their special advantages as material for general biological problems. He did not, however, lose the special in the general, but throughout his life continuously displayed his interest in Protozoa as organisms of a special phylum by significant publications which displayed his comprehensive knowledge of the whole group.

He began his general studies by an examination of Maupas's classical works on senescence, conjugation and rejuvenescence in Protozoa (1888–1889) and of August Weismann's interesting conception of immortality of these organisms (1891). His experiments on *Paramoecium caudatum*, begun in February, 1901, required daily attention for a period of two and a half years. He improved on Maupas's methods in various respects, but especially by keeping exact account of the number of generations by division; this involved isolation of individuals in new culture slides with fresh medium after two or three divisions at the most, that is, about every other day. He found that well-marked periods of depressed vitality occurred at about six-month intervals with less evidence of depression at about three-month intervals, but that these could be overcome by suitable changes of the culture medium, a result that he compared to artificial parthenogenesis, then a new subject. However, there came a time when all treatments failed and the best series finally died out in the 742d generation. His results led him to accept the idea that growing old is a natural phenomenon in Protozoa as well as in Metazoa,

and to reach the conclusion "that the indefinite continuation of life without conjugation is improbable" (1904); in this he was in substantial agreement with Maupas.

He published numerous later papers on life histories of Protozoa, generally with these problems in mind. They took a different form when L. L. Woodruff of Yale University, a former student of Calkins, undertook a day by day study of naturally occurring rhythms in *Paramoecium aurealia* and, in conjunction with Rhoda Erdmann (1914), discovered the phenomenon of "endomixis," a periodic reorganization of the entire nuclear apparatus within single individuals which restores the upper level of the rhythms. Woodruff's cultures of this species were continued to 5,250 generations up to 1915, over a period of eight years, without conjugation or the use of artificial stimuli. Calkins's final statement of the problem in 1934 included endomixis along with conjugation, encystment, reorganization during division, and environmental and metabolic conditions as factors controlling longevity in protozoan protoplasm.

His published researches are a lasting memorial. He was also an enthusiastic and successful teacher and has left distinguished followers who received their inspiration from him to carry on his tradition. His books, products of his research and teaching, were: "The Protozoa," 1901; "Protozoology" (based on lectures before the Lowell Institute in 1907), 1909; "Biology," 1914; "Biology of the Protozoa," 1926 and 1933.

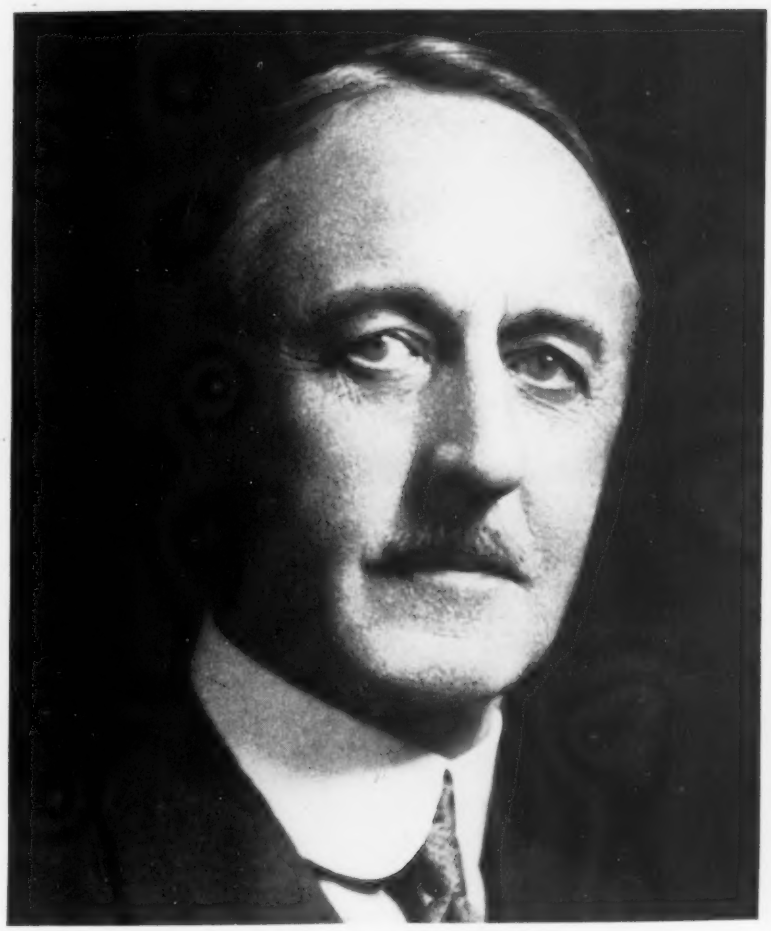
Outside of his more strictly institutional activities Calkins was in great demand. There is space to mention only a few examples. Thus from 1902–1908 he served as consulting biologist to the New York State Cancer Laboratory in Buffalo; from 1919–1921 he was president of the Society for Experimental Biology and Medicine. In 1926–1927 he was director of the University Union in Paris, where he had the opportunity of promoting the interests of foreign students, especially American, in that city and throughout France. But Calkins's principal scientific activities outside of Columbia University were in connection with the Marine Biological Laboratory at Woods Hole, Massachusetts. His connection with the Laboratory dated back to 1893, and he established a summer home there about 1910. After that time he was present for all the summer sessions except for one year in Europe. He was a member of the Corporation for 39 years, Trustee for 30 years, Clerk of the Corporation for 17 years, Secretary of the Board of Trustees for 12 years; he was also investigator there for 35 years, a member of the research staff for 31 years, head of the course in Protozoology for 22 years. His devotion to the Marine Biological Laboratory, his second institution, was unbounded.

He will be remembered for what he was no less than for what he did. Perhaps his most striking personal characteristic was a special quality of lovableness displayed in his relations to his family, his friends and his professional associates, both contemporaries and students. That his gifts of human kindness were reciprocated was shown by the portfolio of about two hundred letters addressed to:

Gary Nathan Calkins
Philosopher in Little Things
and Friend

from his students and friends, presented to him in 1941 after his retirement, expressing their esteem and appreciation. That this testimonial took such a personal form, rather than the more usual form of a congratulatory volume of scientific contributions from former students and associates, is eloquent evidence of the respect and affection that Calkins drew to himself.

FRANK R. LILLIE

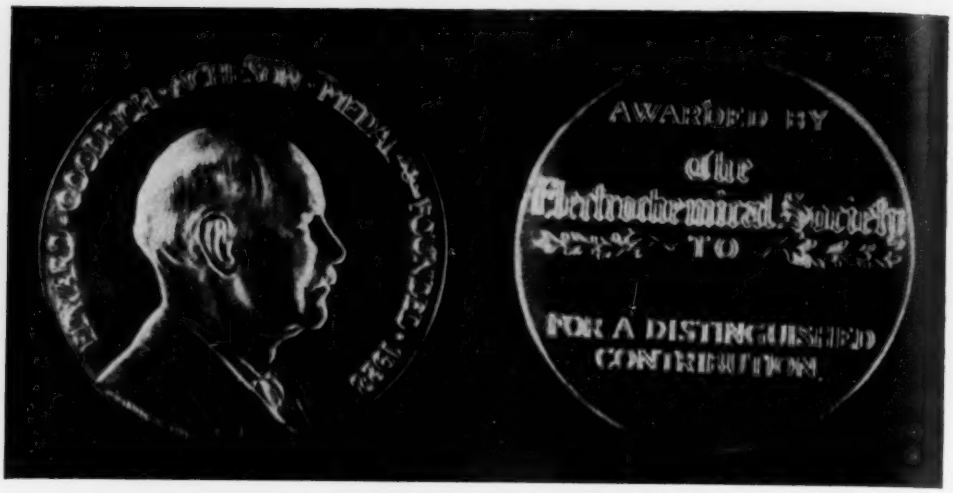


CHARLES FREDERICK BURGESS, EDWARD GOODRICH ACHESON MEDALIST

At its fall convention in 1942 the Electrochemical Society bestowed on Dr. Charles F. Burgess the Acheson Medal and Prize, the highest honor in electrochemistry.[1]

Dr. Burgess' world-wide reputation is based largely on his contributions to the modern dry cell, the "Burgess Battery." When Dr. Burgess originally approached the dry battery problem, forty years ago, there were then so many contradictory reports as to the electrochemical reactions involved and so many complications inherent in the manufacture of a good dry battery that only an investigator with a vision and insight such as Burgess possesses would have considered the problem worth investigating. But characteristic of the Burgess experimental approach and his untiring enthusiasm, the difficulties involved and the causes for irregular battery behavior were solved, one by one, so that within a few years the battery specifications adopted by the National Bureau of Standards were largely based on Burgess' findings.

[1] Previous recipients of the award are Edward G. Acheson, Edwin F. Northrup, Colin G. Fink, Frank J. Tone, Frederick M. Becket and Francis R. Frary.



THE EDWARD GOODRICH ACHESON MEDAL

Another of Burgess' pioneering researches is that on electrolytic iron of almost 100 per cent. purity. All iron electro-deposition baths developed previous to Burgess produced deposits that were either very thin or dark, rough and powdery. Over three tons of pure electrolytic iron were produced in the pilot plant in the Burgess laboratory at the University of Wisconsin. This iron served as the basis of some 1,000 alloys which Burgess tested and otherwise studied.

An outstanding physical property of electrolytic iron is its high permeability and relatively low hysteresis loss. Accordingly, the Western Electric Company at Hawthorne, Illinois, installed a large electrolytic iron plant using the Burgess formula and manufactured rings of electrolytic iron for the Pupin coils used in transatlantic telephony. This Hawthorne plant continued to operate for many years until the advent of the nickel-iron alloys, permalloy and mμ metal, whose magnetic characteristics were even superior to those of pure iron.

Aside from the interesting magnetic qualities and consequent applications of electrolytic iron, Burgess found another property that has led to a new use for this pure iron during recent years. He demonstrated that electrolytic iron can be made very brittle "due to occluded hydrogen." This brittle product is today ground to a fine powder and, with certain alloying additions, is used to make intricate gears and other iron parts more easily manufactured by powder metallurgy methods than by casting or machining. The spent pickling solutions of the steel mills are cheap and "inexhaustible" raw material for electrolytic iron.

Many pages would be required to present the numerous scientific and industrial accomplishments of the medalist. The wide scope and large diversity of the problems and products of the laboratories directed by Dr. Burgess during the past forty years are evidenced by the following partial list: purification of drinking water, standardization of city gas, copper-beryllium alloy springs, aluminum rectifier, copper-bearing steels, sound-absorbing materials, conversion of swamp weeds into useful products, clay building blocks, rubber dispersions, gas filters, sterilizing liquids, corrosion of strained metals, etc.

Dr. Burgess was born in Oshkosh, Wisconsin, on January 5, 1873. His alma mater is the University of Wisconsin (B.S. 1895; E.E. 1898; Sc.D. *honoris causa*, 1926). He taught at Wisconsin for eighteen years. When he was twenty-seven years old Dr. Burgess introduced a course in electrochemistry, one of the first of such courses in America.

The C. F. Burgess Laboratories were founded in 1910 at a time when industrial research had not been generally accepted. The original capital investment totalled $9,000. By 1923 this had increased to $900,000 through earnings and sales of stock.

Dr. Burgess, now past seventy, continues his active interest and participation in the C. F. Burgess Laboratories and in the half-dozen subsidiary companies. At his winter home on Burgess Isle near the west coast of Florida he maintains a well-equipped laboratory where he enjoys testing out ideas that often seem fantastic or impossible to the lay mind.

Dr. Burgess once wrote: "If business incidents are met by the chemist as patiently and cheerfully as he meets the problems involved in laboratory research, the chances for pleasure and profit from his business are excellent."

COLIN GARFIELD FINK

THE YALE LABORATORIES OF PRIMATE BIOLOGY

THE immediate occasion for this note is an announcement by Yale and Harvard Universities of their cooperation in the furtherance of primate research by jointly operating the laboratories at Orange Park, Florida, which heretofore, as the Yale Laboratories of Primate Biology, have constituted a department of the Yale School of Medicine. In this cooperative enterprise the universities have the financial assistance of the Rockefeller Foundation, the Carnegie Corporation, and the Samuel S. Fels Fund. It is stated that the name has

ADMINISTRATION BUILDING, YALE LABORATORIES OF PRIMATE BIOLOGY

been changed to Yerkes Laboratories of Primate Biology, Inc., and that the corporation consists of three representatives of each university.[1]

Responsibility for research and educational activities in the establishment will rest with Director Lashley and a Board of Scientific Directors consisting of: Dean Francis G. Blake, Yale School of Medicine; Leonard Carmichael, President of Tufts College; George W. Corner, Director, Department of Embryology, Carnegie Institution of Washington; Derek E. Denny-Brown, Professor of Neurology at Harvard; Frederick L. Hisaw, Professor of Zoology at Harvard; William H. Taliaferro, Professor of Parasitology at the University of Chicago; and Professor Yerkes of Yale.

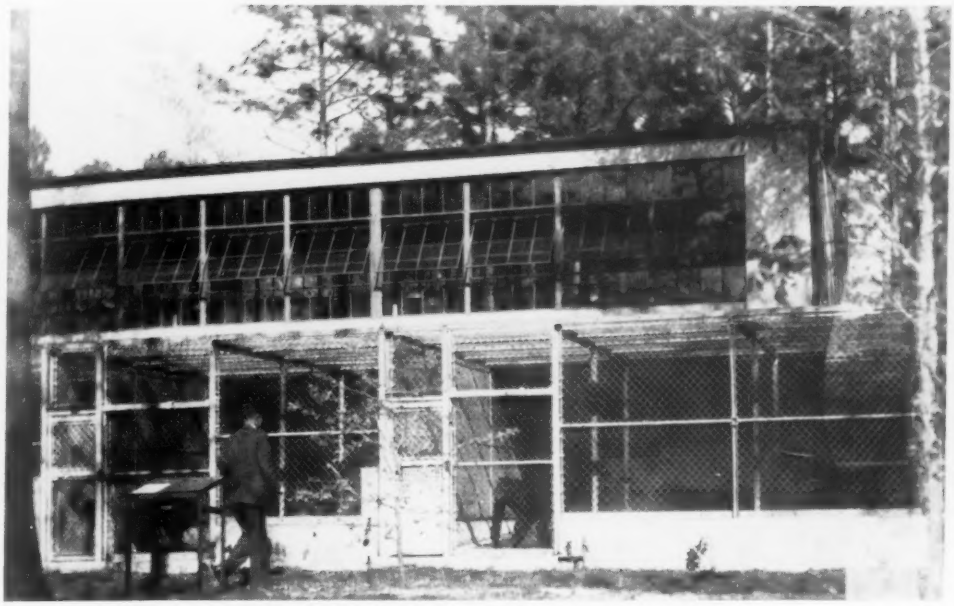
This undertaking had its origin in the Primate Laboratory of the Yale Institute of Psychology, in 1924. Five years later, with the support of the Rockefeller Foundation, Yale established the Anthropoid Breeding and Experiment Station at Orange Park, Florida. Since its opening in 1930 the Station has developed steadily and, in large measure, the original objectives have been achieved. The site of some two hundred acres has proved almost ideally suitable for the project and a number of permanent buildings have been erected, the most recent of which are a modern laboratory building and quarters for monkeys.

Starting with four chimpanzees as nucleus of an anthropoid breeding colony, all of which had been born in Africa and were of unknown age and life history, the Laboratories had in 1942 a col-

[1] From Harvard, James B. Conant, President, William B. Claflin, Jr., Treasurer, Henry L. Shattuck, Fellow of Harvard College; from Yale, Charles Seymour, President, Thomas W. Farnam, former Associate Treasurer and Comptroller, and Carl A. Lohmann, Secretary. Dr. Karl S. Lashley, Research Professor of Neuropsychology at Harvard, has been appointed Director of the Yerkes Laboratories and Dr. Henry W. Nissen, Associate Professor of Psychobiology at Yale, Assistant Director. Dr. Yerkes, as Director Emeritus, continues as Professor of Psychobiology at Yale.

A VIEW OF THE LABORATORY BUILDING

SHOWING THE OPEN CORRIDOR CONNECTING IT WITH THE ADMINISTRATION BUILDING.



A NEAR VIEW OF ONE END OF THE ANIMAL QUARTERS BUILDING

ony consisting of about fifty individuals. There have been nearly that number of births in the Laboratories.

Dr. Lashley in reviewing and appraising the history of this project points to the following three initial objectives as essential to its successful development.[2] "Foremost of these was the development of methods for the breeding and rearing of healthy stock and the establishment of a colony of known age and history. This aim has been fully achieved. A second objective was a broad psychobiological study of the chimpanzees, for the light which it might throw upon the origins of human biological and social traits. Such a study can never be completed . . . but the reports from the Station now present an integrated account of the physiological and psychological characteristics of the chimpanzee which is more nearly complete than that available for any other animal except, perhaps, the rat. A third objective in the original plan was to determine the suitability of the chimpanzee as research material for the investigation of various questions of physiology, psychology and medicine, and to develop the lines of investigation in which the animals could be used to best advantage. Several such fields of research for which the chimpanzee is uniquely adapted have been defined and work in them initiated. Priority of the breeding program thus far has restricted work mainly to problems which did not require sacrifice of the animals. The chimpanzee colony has now reached the maximum size which can be maintained with the facilities of the Station. An adequate supply of animals for more radical experiments may be anticipated."

Looking beyond the present vantage ground of achievement into the future of research with the higher primates, Dr. Lashley concludes that "The general fields of investigation which promise immediate, valuable results at the present stage of development of physiology and

[2] Quoted from an unpublished "Program for Research at the Station."

A GLIMPSE OF THE VEGETATION ABOUT THE ADMINISTRATION BUILDING

psychology are the 'dynamics' of behavior and the nature of 'intelligence'."

The new director has laid out a plan of research which includes several groups of related psychobiological problems. Notable among them are (1) ontogenetic and phylogenetic studies of growth and intellectual capacities in the primates; (2) analysis of sexual behavior in its relations to neural and endocrine functions; (3) descriptive studies of individual differences in temperament and emotional reactions; and (4) studies of the physiology of the central nervous system in relation to instinctive and intellectual capacities as revealed in the above types of analysis of behavior. The resources of the Laboratories have been supplemented by the purchase of a group of spider monkeys from which it is hoped to develop a breeding colony of experimental animals.

Primary emphasis will be placed on the research use of monkeys and apes as approach to the solution of human problems and as basis for the development of new phases of human engineering.

ROBERT M. YERKES

CRANBROOK INSTITUTE OF SCIENCE EXHIBIT OF MICHIGAN PLANT LIFE

AGASSIZ's admonition, "Study Nature not Books," is being followed in the Cranbrook Institute of Science at Bloomfield Hills, near Detroit, Michigan. In its recently opened Hall of Plant Associations there are seven dioramas, showing typical examples of important Michigan plant communities.

Ranging over seven degrees of latitude and eight of longitude, Michigan comprises great diversity of terrain and vegetation types. Lower Michigan lies in the deciduous forest zone with two forest climaxes; oak-hickory and beech-maple. Upper Michigan is in the lake forest vegetation zone. Here evergreen trees are dominant and the coniferous forest is climax. As one progresses northward in the state pines become more plentiful, hickories drop out of the picture, oaks decrease in number and beaches finally disappear. These diverse climax types are direct responses to the great differences in climate, soil factors and physiography of the northern and southern parts of the state. They reflect the geologic history of Michigan and particularly the effect of the ice age upon her soil and countours.

In Cranbrook's Hall of Michigan Plant Associations typical examples of the three climax forests, conifer, oak-hickory, and beech-maple are authentically reproduced. With them are shown four other Michigan plant communities which are transitional and successional communities leading up to the three climaxes.

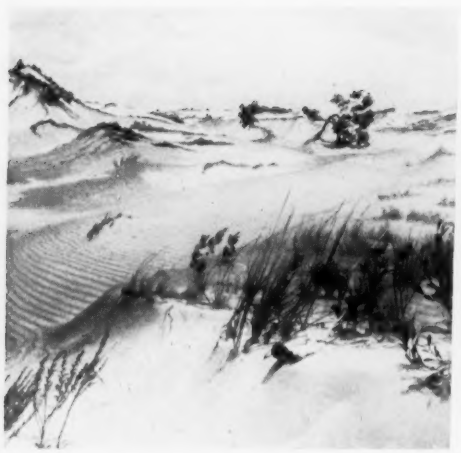
The rich deep coniferous forest near the tip of the Keweenaw Peninsula has been reproduced as it appears in late August. Beneath pines, balsam, spruce and cedar grow arbutus, starflower, pipsissewa and bunchberry with its clusters of bright red fruits. In dense shade only thick mats of dark green moss and tufts of reindeer lichen grow in the fragrant needle carpet. Such forests develop through long stages of growth and change. They may begin from such apparently remote origins as cobble beaches on the northern shores of Lake Huron or the sun washed dunes of Lake Michigan's eastern shore.

Typical of these cobble beaches is the south shore of Bios Blanc Island, in the Straits of Mackinac, as shown in the Cranbrook exhibits. Here is clearly evident the trend of succession from water's edge, through a flower strewn beach where fringed gentian, pink foxglove and green and white grass of parnassus abound to the wave-free high beach where the evergreen forest wall rises abruptly.

Sleeping Bear Dune, Leelanau County, the largest moving dune in Michigan, has been selected as best exemplifying the transition from loose shifting sand to capture by coniferous forest. A portion of this extensive dune is shown as it appears in August. Wind swept areas where plant life is reduced to sparse growth of dune grass; quiet places where dune thistle, wormwood, harebell, and puccoon gain footing; as well as twisted poplar trees, a fossil forest, and typical "blow-out" are shown. Here also is seen a partially held dune known as a "Gibraltar" and a completely captured and forested dune, the Great Bear, perched on a bluff many hundred feet above Lake Michigan.

SPRUCE–CEDAR BOG

PINK AND WHITE, YELLOW AND STEMLESS LADYSLIPPERS GROW IN AN ACID SPHAGNUM BOG WITH CRANBERRIES AND PITCHER PLANTS. BLACK SPRUCE, CEDAR AND TAMARACK TREES SHELTER THESE DELICATE PLANTS.



SAND DUNE

HERE, ON SLEEPING BEAR, MICHIGAN'S LARGEST MOVING SAND DUNE, WIND-BLOWN SAND CHERRY, WORMWOOD AND SAND-BINDING GRASSES INDICATE THE DIRECTION OF PREVAILING WINDS. A FOSSIL FOREST, BLOW-OUT AND PARTIALLY CAPTURED AREAS ARE ALSO SHOWN.

OAK–HICKORY FOREST

ON WELL DRAINED MORAINIC SOILS, FORESTS OF OAK AND HICKORY SHELTER DELICATE SPRING BLOOMING TRILLIUMS, VIOLETS, JACK-IN-THE-PULPIT AND MANY OTHER EARLY-APPEARING WILD FLOWERS WHICH FADE WITH THE INCREASE OF THE LEAFY CANOPY AND HIGHER TEMPERATURES.

Trending toward the two hardwood forest climaxes characteristic of lower Michigan are many transitional groupings of plants. Two are shown in the Hall of Michigan Plant Associations.

A spruce-cedar bog in the southern part of the state has been selected as outstanding. These bogs trace their origin to glacial times when blocks of ice, slow in melting, left depressions more or less filled with cold water. Boreal plants usually found in latitudes far to the north have become well established in these situations, but disappear when the bog silts in and the water table changes.

In the bog shown at Cranbrook moisture-retaining, moss-covered hummocks and dark lily-covered pools are sheltered by pyramidal black spruce, tamarack and cedar trees. Here in these difficultly penetrated bogs grow rare orchids like the yellow, pink and white and stemless lady's slippers. With them fragrant rose pogonia, cranberries, pitcher plants and wild white calla lily are found. Sheltering shrubs are chiefly blueberry, rosemary and poison sumach.

Frequently, as the water table changes dry meadow succeeds wet bog. Here in the absence of all shade, sun-loving wild carrot; chicory; Black-eyed Susan and bee balm grow in a dense matrix of timothy and blue grass. Such an open meadow in southern Michigan has been reproduced in Cranbrook's plant hall.

As shrubs and trees gain foothold, meadow plants disappear. If the terrain be well drained and of light textured soil, oak-hickory forest will succeed dry meadow. Such a forest as it appears in May with its profuse carpet of shade-loving delicate flowers is shown. Under sheltering oaks and hickories with wild cherry and shadbush bloom hepaticas, trilliums, blue violets, May apple, Jack-in-the-Pulpit and Dutchman's breeches.

Of distinct contrast to the flower strewn forest floor of typical oak-hickory forest is the clear open sweep of mature stands of beech and maple. In this woodland only a few herbs are seen. Ferns, beech drops and Indian pipe grow here. Occasional red-berried elder, Virginia creeper and trailing bedstraw augment

the scant growth. Beech and hard maple trees with a few butternuts and tulip trees form the forest canopy.

Cranbrook Institute of Science presents these seven reproductions of Michigan plant life for the pleasure, the inspiration and the education of the people. Here they may be seen not only by those familiar with their originals but by many never able to seek their counterparts in reality. For the teacher and the student they are a book of three-dimensional illustrations. For the casual visitor there is pleasure and stimulation to a better appreciation of our natural surroundings. For all, there is conservation of a high order and silent appeal for the preservation of some of our richest resources.

MARJORIE T. BINGHAM

DEVELOPMENT OF INTERACTIVE SOLAR PROMINENCES

PROMINENCES on the sun are roughly divided into five classes; Quiescent, Active, Sunspot, Eruptive, and Tornado. The ordinary active prominences are those from which streamers are pulled into centers of attraction located anywhere over the solar surface. In the sunspot, active type streamers are pulled into centers of attraction located within a sunspot area. So far as we know both these types of prominences may disappear principally in three ways: (1) by shredding, *i.e.*, they are torn apart and pulled into the sun in the form of streamers, (2) by a quasi-eruption which occurs when the shredding becomes very rapid, the whole prominence rises, moves over an arc and down into the center of attraction on the sun, and (3) by an eruption when, for some unknown reason, the prominence begins to rise, moves away from the sun, then disappears by fading out at an elevation which often amounts to several hundred thousand kilometers.

Occasionally the prominence will divide, a part becoming quasi-eruptive and a part eruptive. In any event streamers continue to rain down to centers of attraction upon the sun as the prominence rises. The characteristics of the movements of prominences point to electrical charges rather than light pressure as the motive force. Since the study of prominences without an eclipse began 73 years ago, 64 eruptive prominences have been found to follow this pattern of development.

A rare form of the active type is the interactive prominence in which two or more prominences are connected by streamers. Very little was known about this type. On August 7 and 8, 1942, one was photographed with the newly de-

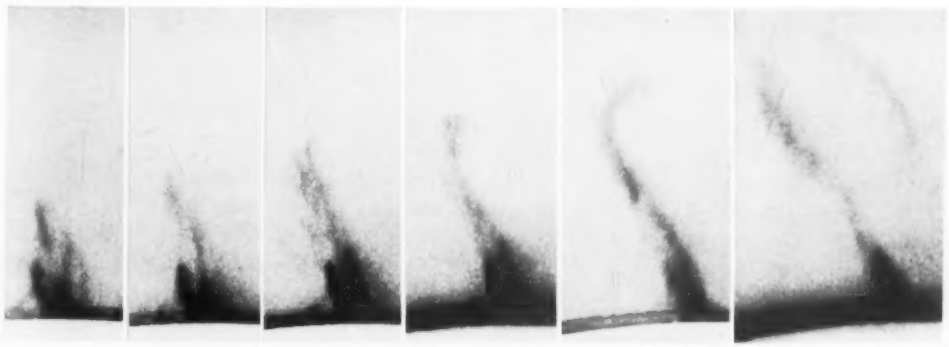


FIG. 1. ERUPTIVE PROMINENCE OF OCTOBER 6, 1942
EXPOSURES AT INTERVALS OF 23 MIN. HEIGHT OF PROMINENCE IN THE LAST PICTURE 250,000 KM.

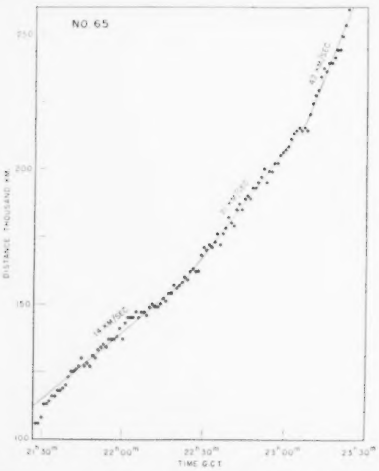


FIG. 2. TIME–DISTANCE DIAGRAM OF THE ERUPTIVE PROMINENCE OF OCTOBER 6, 1942. STRAIGHT LINES IN THE DIAGRAM SIGNIFY UNIFORM MOTION. VELOCITIES ARE INDICATED.

veloped monochromator which showed that the prominence gases in a pair of streamers were moving in opposite directions. This movement of gases from one prominence to another seems to require that electric charges of either sign may occur in a prominence. Why such a prominence does not collapse is a mystery, for the ionized calcium atoms, which always form part of the gaseous material, have the positive sign only. There is no difference in the forms of prominences photographed in ionized calcium or neutral hydrogen.

Of the development and distinction of interactive prominences very little is known. One which crossed the disk in July, 1941, was converted into a pair of ordinary active prominences when two centers of attraction developed beneath the connecting streamers and pulled them into the sun.

On October 6, 1942, an interactive prominence which appeared on the west limb of the sun developed into an eruptive prominence. When first seen it was a pair of comparatively small prominences consisting of one 35,000 kilometers high pouring fine streamers into another 14,000 kilometers high 60,000 kilometers south of it. By early afternoon the pair of prominences were fused into a single unit which had risen to more than 100,000 kilometers and photography was continued until it was lost in an overcast sky at $23^h\ 24^m$ G.C.T.

From the monochromator film on which exposures were recorded at 1-minute intervals we have selected the 6 exposures at 23-minute intervals shown in the accompanying photograph. In the first exposures the prominences are seen blended into a triangular form. This grows into a column which bends over and a streamer is pulled back upon the sun as the prominence rises.

This prominence moved along a trajectory which, extended backward to the sun, made an angle of 34° to the solar radius. The measures of the distance of the top of the prominence from the sun were made along this trajectory which was sensibly straight and the resulting time-distance diagram is shown in Fig. 2.

The straight lines shown in the photograph indicate that the velocity was constant, except when it increased rather abruptly at intervals. The slopes of the lines indicate velocities of 14, 21 and 42 kilometers per second. In other eruptive prominences which we have studied each velocity is usually a small hole multiple of that preceding. This case illustrates one of the variants in which an interpolative velocity appears although we can not tell whether it is the first or second velocity since they are both factors of the third.

From this brief account of the present state of our knowledge of interactive prominences it will be seen that evidence is accumulating which indicates that the active and interactive types have common characteristics.

EDISON PETTIT